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IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY.

NOTES AND MEMORANDA.

On the Pathogenicity of *Heterodera schachtii* to Potatoes and Mangolds.

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Introduction.

In 1925, Morgan, in recording field observations on *Heterodera schachtii* in the Kirton district, pointed out that cysts were frequently as abundant in certain areas of infected fields where the yield was satisfactory, as in " bad patches " where the plants showed every manifestation of eelworm disease, and where the crop was a failure. In a further publication (1926) he again emphasized the lack of correlation between cyst content of the soil and the incidence of " potato-sickness." One field on which detailed observations were carried out, although the worst case of eelworm infestation examined in the district, was found to give a satisfactory crop—average yield eight tons ware per acre—after only a four year rotation. In summing up these observations, Morgan says : " While it is not suggested that the eelworm had no influence on the yield in this instance, the success of the crop in spite of the pest lends support to the view that the problem is primarily one of obtaining more suitable conditions for plant growth by more judicious manuring and a system of rotation."

In 1929 Smith and Prentice confirmed Morgan's observations, and further found that, although in infestations of long standing there was no positive association of intensity of disease and cyst content of the soil, yet such association did exist in cases where the disease had only recently been observed. Further, Smith and Miles in another paper reach the conclusion that " eelworm infestation is not of primary importance in determining the yield of potatoes, and that cysts tend to increase in number only on a crop which is not a failure, but which has been adversely influenced by some other factor."

Miles (1930) recorded the results of field studies and pot experiments on the relationship of the eelworm alone, and combined with other factors, viz., attack by the fungi *Colletotrichum tabificum* and *Corticium solani*, to " potato-sickness." Under otherwise good growing conditions the tolerance of the potato plant to eelworm attack was found to be high. Loss of efficiency due to eelworm damage in the root tissues, was apparently made good by the increased production of lateral roots, and the presence of intense eelworm attack was found to be insufficient to produce any noticeable pathological condition in the host. The combined attack of eelworms and *Corticium solani* was found under certain conditions, to be insufficient to influence the yield, the fungus causing only a temporary check in growth early in the season, from which the plants soon recovered. *Colletotrichum tabificum* was found to hasten the destruction of the plants in autumn and was thought to be a possible contributory factor to the condition known as " potato-sickness."

From these and other descriptions of the occurrence of the symptoms of " potato-sickness " it is evident that, although *Heterodera schachtii* is constantly present in " potato-sick " soil, it also frequently occurs in soil which is not " sick," and which produces a good crop despite the presence of the parasite. Thus it appears that the eelworm, although not the primary pathogenic factor, may yet be the decisive agent in the production of disease. Under these circumstances it follows that the extermination of the nematode would in all probability be accompanied by the dying out of the disease.

The nature of the primary factor, or predisposing condition, remains unknown, although from Morgan's observations it appears to be eliminable by the adoption of suitable crop rotation combined with careful manurial treatment of the soil. The high degree of toleration exhibited by the potato plant to comparatively intense nematode infestation has been repeatedly observed, but hitherto little has been done to estimate the extent of the damage suffered by this host. Histological investigations of parasitised plants have shown that a considerable amount of damage is done by *H. schachtii*, both to potato and mangold plants, although the extensive root system of the former enables the plant to maintain a more nearly normal physiological efficiency than is the case in parasitised mangolds.

FIELD OBSERVATIONS.

A plot of land was infected in 1926 at the Institute's Field Station, by laying down infected Lincolnshire soil in two drills throughout the length (99 feet) of the plot. Potatoes have subsequently been grown over the whole plot for five successive years and the spread of the parasite, and appearance of disease symptoms, have been noted annually.

In 1929 the first symptoms of disease in the crop was manifest in the early withering and dying down of the haulms in the two rows originally infected. Although the infection had spread to the two adjacent rows towards the middle of the plot, it was, in them, much less intense, and the plants appeared to be normal. The yield from the two rows originally infected was considerably less than from the uninfected portion of the plot.

In 1930 the pathological symptoms were more marked, and made their first appearance in the third infected row. The first two rows showed a slight initial check in growth, followed by stunting of the haulms, yellowish colour of the foliage and early dying down of the tops. Again the yield was markedly reduced, although the crop was not a complete failure.

The length of time between the establishment of the infection and the appearance of pathological symptoms in the host, in the case of the potato, is in direct opposition to the results obtained with mangolds. A small plot of land was experimentally infected with a strain attacking mangolds in the spring of 1929, and mangolds were noticeably affected in the same year. In the first season (1929) no initial check to growth was observed during the first two months, but throughout the summer the presence of direct sunlight was accompanied by considerable flagging and wilting of the plants in the infected area. This was followed by the gradual dying off of the outer foliage, and, on lifting, the plants showed poor tap-roots, many of them distorted and bifurcated, with an abundance of lateral rootlets, giving the typical " whiskered " appearance well known in eelworm-infested sugar beet. Cysts were present on the roots of these plants in large numbers, and the cyst-content of the soil was considerably increased. In 1930 the plants showed an early check in growth which had not been noted the previous season, and again, wilting, and dying of the outer leaves was strongly evident.

The speedy manifestation of disease symptoms in this host is no doubt due to the limitation of the absorptive root system entailed by the tap-root.   Impaired efficiency of the lateral roots when these are attacked and damaged by eelworms is less easily made good by the development of secondary laterals than in the potato plant, where an extensive fibrous root system is normally present.   Hence it may be said that the mangold exhibits a very slight degree of tolerance to the pest as compared with the potato.

EFFECTS OF *H. schachtii* AS SHOWN BY DRY WEIGHTS OF PLANTS.

The field observations of other workers, and the writer's experience with pot and field experiments having shown that *H. schachtii* is not the sole cause of " potato-sickness," attempts were made to determine whether the presence of the nematode alone, under otherwise good con-ditions, could cause sufficient damage noticeably to affect the growth of the plant.

For this purpose, as an initial experiment, ten healthy tubers bearing sprouts of approximately equal size, were selected, and with a corkborer cylindrical cores of the tubers were prepared, each bearing one shoot, and weighing 3·5 grams.   These were planted in small pots of clean loam which had been partially sterilised by steam.   To the loam in five of the pots, cysts which had been isolated from an equal quantity of infected soil, and had subsequently been sterilised by thirty minutes immersion in a three per cent. solution of H_2O_2, were added.   The plants were grown under observation for one month, when they were carefully removed from the soil, washed, and, after being thoroughly dried in a hot air oven, were weighed.   The average weight of the infected plants was found to be 0·146 grams, and the average weight of the uninfected plants 0·501 grams.   That is, the average dry weight of an infected, as compared with an uninfected plant, was as 1 to 3·4.

This experiment was repeated, using ten cores of five grams each in weight for both the experiment and the control, and on this occasion the plants were allowed to grow for two months before being weighed.   The weights of the infected plants ranged in this instance from 0·264 grams to 1·847 grams, with an average weight of 0·749 grams.   The plants grown in clean soil were found to vary in weight from 0·919 grams to 4·255 grams, with an average weight of 2·0277 grams.   Thus in this

instance the average dry weight of an infected as compared with an un-infected plant was as 1 to 2·7.

From these results it was concluded that the presence of *H. schachtii* parasitic upon the roots of potato plants was sufficient cause in itself to check the early growth of the plants, although a comparison of the results of the first and second series of experiments possibly indicates that the effects of this check are made good comparatively early in the growing period.

EFFECTS OF *H. schachtii* ON THE RATE OF TRANSPIRATION.

Some simple physiological methods were applied to test the efficiency of water conduction in infected plants. For advice concerning these the writer is indebted to Miss C. Halket, to whom she wishes to express thanks. Potometer tests were found to be unsatisfactory as they were impossible to apply to plants grown in the field, and infected plants grown in soil were found to lose many of the adherent nematodes when transferred to water culture solution preparatory to use in the potometer. The cobalt chloride method was therefore applied both to field-grown and potted plants. Two standard colours, deep and light blue, were prepared, and strips of filter paper soaked in a solution of cobalt chloride were fastened between strips of the two standard colours. The test was then applied as follows. The prepared papers were dried over a spirit lamp until the cobalt chloride paper corresponded in colour with the deeper of the two standard colours. The whole slip was then applied to the under surface of the leaf whose transpiration rate was to be tested, and was covered with a dry glass slide. The time that elapsed before the cobalt chloride paper faded to the paler blue of the second standard slip was measured, and this gave a rough idea of the rate at which transpir-ation was taking place in the leaf. Direct sunlight was avoided and leaves of approximately the same age were chosen within each series of tests.

Potted plants grown under uniform conditions from specially prepared cores of healthy tubers were used in the first instance. The plants were grown in partially sterilised soil to which sterilised cysts had been

added to form an infection in half of the plants used. It was assumed
that *H. schachtii* was the only pathogenic factor operating in this series
of experiments. The third leaf from the growing point of each of the
five infected and five non-infected plants gave the following results :—

Infected plants   ...   ...   Minimum time, 0 mins. 35 secs.
                                 Maximum   ,, 1 min. 35 secs.
                                 Average   ,, 1 min.   0 secs.
Clean plants   ...   ...   Minimum   ,, 5 mins. 15 secs.
                                 Maximum   ,, 10 mins. 0 secs.
                                 Average   ,, 6 mins. 45 secs.

The results of tests on the third leaf from the base of the stem in these
plants were :—

Infected plants   ...   ...   Minimum time, 1 min. 15 secs.
                                 Maximum   ,, 5 mins. 45 secs.
                                 Average   ,, 3 mins. 7 secs.
Clean plants   ...   ...   Minimum time, 3 mins. 20 secs.
                                 Maximum   ,, 5 mins. 30 secs.
                                 Average   ,, 4 mins. 51 secs.

The experiment was repeated under exactly similar conditions using
a new series of ten infected and ten clean plants and testing the third
leaf from the growing point. The following results were obtained :—

Infected plants   ...   ...   Minimum time, 2 mins. 0 secs.
                                 Maximum   ,, 4 mins. 5 secs.
                                 Average   ,, 2 mins. 54 secs.
Clean plants   ...   ...   Minimum time, 1 min. 50 secs.
                                 Maximum   ,, 3 mins. 30 secs.
                                 Average   ,, 2 mins. 32 secs.

As these results were obviously inconclusive the test was applied
to twenty infected and twenty uninfected plants on the field plot. The
infected plants selected were apparently free from fungus and virus
diseases, and showed no signs of " potato sickness." The sixth leaf
from the growing point of the strongest shoot of each plant was selected
for trial. Again great variations were noted in the times, but as in
the second series of potted plants the average times for clean and infected
plants differed only slightly. The maximum, minimum and average

times are given below :—

Infected plants ...	...	Minimum time	1 min.	45 secs.
		Maximum ,,	2 mins.	15 secs.
		Average ,,	2 mins.	0 secs.
Clean plants ...	...	Minimum time,	1 min.	15 secs.
		Maximum ,,	5 mins.	0 secs.
		Average ,,	2 mins.	27 secs.

From these results it was concluded that the presence of *H. schachtii* parasitising the roots of potato plants had little or no effect on the rate of transpiration. Since an increased production of lateral roots occurs as a host reaction to the presence of the nematode it may be assumed that the new roots thus formed make up for any loss of efficiency on the part of the roots attacked by eelworm. As the experiment was designed to test the effects of *H. schachtii* apart from other factors and those plants which showed symptoms of " potato sickness " were beginning to die down when the experiment was performed, the transpiration rate of " sick " plants was not tested.

Mangolds under field cultivation showing the effects of eelworm attack were available for experiment and the same test was carried out on twenty infected and twenty uninfected plants. The work was carried out on a sunless day when the infected plants showed no signs of wilting, and leaves of the same age, as far as could be judged, were selected for trial.

The results of these observations were strikingly different from the results obtained from the potato plants. Not only did the times necessary to complete the tests show comparatively little variation, but in infected plants the transpiration rate was found to be much slower than in the clean plants, as is shown by the following results :—

Infected plants ...	...	Minimum time,	0 mins.	50 secs.
		Maximum ,,	3 mins.	15 secs.
		Average ,,	1 min.	33 secs.
Clean plants ...	...	Minimum time,	0 mins.	15 secs.
		Maximum ,,	1 min.	5 secs.
		Average ,,	0 mins.	35 secs.

Some of the plants were dug up immediately following these tests and it was found that already the formation of additional lateral roots had taken place to a considerable extent, while evidences that still

further root proliferation was in progress were also apparent. Throughout the whole of the summer the infected plants were kept under observation, and flagging was seen to continue in direct sunlight until the plants were removed from the ground. It therefore becomes obvious that in this instance the reactions of the plant to the parasite were not successful in counteracting the injurious effects of the latter.

The Effects of Excess of Root Excretions on the Growth of Plants.

Since *H. schachtii* alone is apparently insufficient to cause severe pathological symptoms in the potato plant, and field observations have so far failed to determine the nature of the other factor or factors involved, some tests were carried out of the effects of root excretions on the growth of plants. This was undertaken as a result of a previous observation that a plant supplied only with water containing mustard root excretion showed signs of etiolation and a tendency to die down prematurely. Further it was known that potato root excretion was quickly broken down in soil and that " potato sickness " was usually most severe where potatoes were grown consecutively over many years. It was therefore thought that an accumulation of potato root excretion, or its decomposition products, might constitute a hitherto unrecognised factor in the production of disease, by influencing adversely the growth of potato plants, and preventing the secondary roots being formed sufficiently quickly to neutralise the damage caused to the primary roots by eelworm invasion.

A series of experiments to test this suggestion was therefore carried out as follows. Thirty tubers bearing sprouts of approximately equal size were selected, and cores of 5 grams in weight each bearing one sprout were prepared as described above. These were planted in clean loam in six-inch pots in April, and grown in a cool greenhouse. Six of the plants were watered with the fresh leachings from pots of mustard seedlings, and six with mustard leachings which had been stored in bottles containing a handful of top spit soil to facilitate bacterial and other growths for not less than one month. Six plants were watered with fresh potato root excretion obtained daily by collecting leachings from potted potato plants, and six with old potato root excretion which

had, like the old mustard excretion, been stored with top spit soil for not less than a month. The last six plants were given plain water and served as controls. The plants were given equal quantities of the above solutions daily, and their growth and development were carefully watched. From the beginning the growth of the control plants was slower than that of the plants treated with root excretions, and in mid May the haulms of the six controls were only about two-thirds the height of those of the experimental plants. The latter were then uniformly strong and showed luxuriant foliage of good colour. No differences could be distinguished between the growth of the various groups of treated plants. About this time the rate of growth slowed down in the plants receiving root excretions, but not in the control plants. On June 20th the control plants were indistinguishable from the plants receiving root excretions, and although the treatment was continued, no further differences were observed. Towards the end of July all the plants showed signs of dying down, the foliage yellowing and dying off in the usual way more or less simultaneously throughout the whole series.

It was concluded from this experiment that the root excretions of potato and mustard plants, whether fresh or broken down by organic means, had not, when taken alone, any pathogenic action on the growth of potato plants. Whether in the presence of other pathogenic factors they might continue harmless remained unknown.

Their stimulant action on the early growth of the plants is of interest in view of certain observations of Spencer Pickering and the Duke of Bedford on the effects of grass root excretions on the growth of fruit trees.

Other experiments to determine the effects of excess of root excretions on potato plants grown in soil containing *H. schachtii* gave inconclusive results and are being repeated on a larger scale.

Cellular Reactions of the Host Plant to *H. schachtii*.

Němec (1910,1911) published a detailed account of the effects of *H. schachtii* on the histological structure of eelworm infested roots of the sugar-beet. Transverse sections of infected roots disclosed the presence of groups measuring 0·4 mm. to 0·7 mm. in diameter, of greatly enlarged cells of abnormal appearance. The presence of these cells was

associated with reduction and distortion of the normal vascular elements. These abnormal cells, named by Němec " giant cells," were found to originate in apposition to the head parts of the worm, in the tissues adjacent, but external to, the endodermis. Němec found that the nematode entered the young root at a time when the vessels were not fully differentiated, the parenchyma cells in approximation with the buccal regions of the worm enlarged, partially fused together by the breakdown of some longitudinal and many transverse walls, to form multinucleate syncytia, and assumed the character of giant cells. These
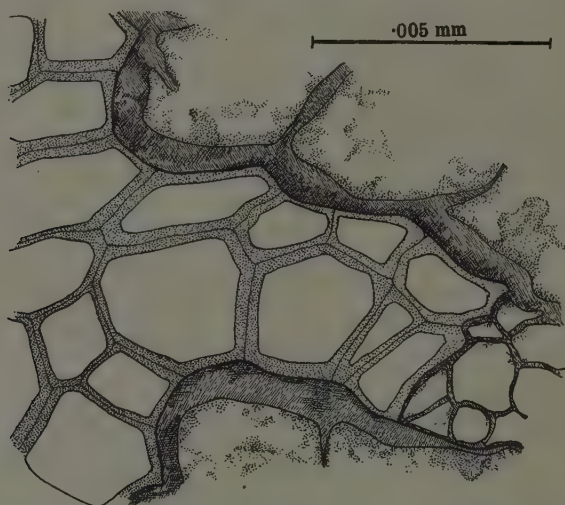
Fig. 1.—Giant cells extending into xylem in potato root.   Transverse section.

remained rich in cytoplasm as long as the worm continued to suck, and their walls became thickened, particularly where they came into contact with the head-parts of the worm and the vascular elements of the roots. Němec suggested that the formation of the giant cells resulted from a stimulating secretion given off from the head of the worm, which brought about an intense metabolism in the affected cells, thus insuring a plentiful supply of nourishment for the parasite. In addition to the purely mechanical damage caused by the thrust and growth of the giant cells,

resulting in crushing, tearing and distortion of the already differentiated vessels, the development of the cambium in the affected regions was arrested, and the formation of metaphloem and metaxylem was prevented. The modified vascular bundles then exhibited an entire lack of vessels with large lumina, the small vessels which remained being either crowded together or dispersed, and the elongated giant cells, which might be as much as 0·7 mm. in diameter and 1·09 mm. in length, extended among them forming plugs which effectively limited the flow of plant foods in either direction.   In addition to this, Němec found that, particularly
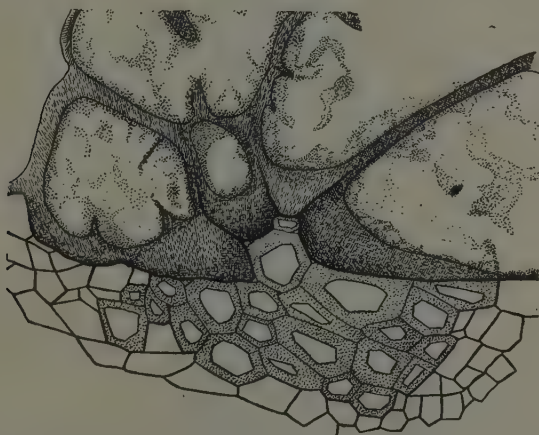
Fig. 2.—Giant cells abutting upon vascular bundle in mangold root.   Transverse section.

following the removal of the worm from the root, fungi and bacteria entered the plant by the wound in the epidermis, extended through the syncytia and among the intact portions of the bundles, more especially the phloem.   The blackening and rotting of the crown of infected plants Němec attributed to these secondary infections.

Histological examinations of potato roots attacked by *H. schachtii* were carried out, and changes similar to those described by Němec were found to have taken place in the tissues.   As in sugar beet, the giant cells were found to originate in the cortical tissues and extend inwards, in some

instances almost to the centre of the steele. Morphologically they resembled the giant cells formed in the sugar beet, although the thickening of the cell walls in contiguity with the walls of the vessels was less marked.

Fig. 3.—Longitudinal section of giant cells in parenchyma, potato root.

Since the eelworms attacking potato roots tend to occur more or less close together in linear series, the reaction zones engendered by individual nematodes were found to coalesce, frequently causing the formation of giant cell complexes of three or more millimeters in length.

Although the giant cells in the potato formed longer syncytia the inward extension of the abnormal elements towards the centre of the steele seemed less marked, and the vascular elements showed less distortion and suppression in this host than had been described for the sugar beet. Where the damage caused by several nematodes extended into a single

Fig. 4.—Longitudinal section of steele of potato root, showing intrusion of giant cells.

transverse section, the area of normal vascular tissue might be reduced by about one half, but the total suppression of all vessels with wide lumina did not occur. Longitudinal sections, however, showed that although many of the larger vessels persisted, the continuity of these was frequently broken by the intrusion of giant cells into the steele, either above or below the point at which they appeared in transverse section to be normal. Thus, although the larger vascular elements were not

suppressed in the potato, their efficiency was frequently entirely de-
stroyed by the intrusion of giant cells which acted as a plug in the water-
carrying system.

Examinations of the roots of infected mangolds showed histological
changes in this plant corresponding morphologically with those described
by Němec in the sugar beet. The smaller roots, however, showed in
some cases even greater damage than Němec had described, the giant
cells extending through the centre of the root and leaving only a few
widely separated groups of three or four small vessels to represent the
steele.

Both transverse and longitudinal sections of potato roots grown in
Lincolnshire soil in pots and in the field plot infected with Lincolnshire
soil at Winches Farm, were found to contain the mycelium of a fungus,
and later microscopic inspection of roots showed small black fructifications
within the root tissues when these were broken across. The sections
showed that the mycelium was commonly present in the giant cells and
in the normal parenchymatous elements of the roots, while it could also
be found both within and between the vessels of the xylem. Only plants
infected with *H. schachtii* were found to harbour the fungus, and it re-
mains to be definitely established whether penetration of healthy root
tissues can be effected by the fungus alone without the intervention of
some other lesion-producing organism such as the nematode. Prelimin-
ary experiments have, however, given some indication that the latter is
not the case.

The identification of this fungus parasite has been kindly undertaken
by Mr. Ramsbottom, of the British Museum of Natural History, who has
established that it is not *Corticium solani* or any of the more common of
the potato attacking fungi. Until a definite diagnosis has been made
and further experimental work carried out the full significance of this
parasite as a factor in " potato-sickness " can not be estimated.

CONCLUSIONS.

From the foregoing remarks it becomes evident that although *H. schachtii* seems to be the determining factor in the production of " potato sickness " the damage that is done to the plant by the nematode can, if suitable growing conditions prevail otherwise, be overcome by the production of new roots, and a satisfactory crop be produced. It has been shown experimentally that an early check to growth is suffered when *H. schachtii* is the only pathogenic factor, but there is evidence that this temporary check is made good by an increase in the production of secondary roots, and that in infected plants that are not " potato sick " the transpiration rate is not reduced.

Mangolds, on the other hand, are much more easily affected pathogenically by the nematode, probably on account of the limitation of their normal root system.

Some other factor or factors are thought to be responsible for the production of disease symptoms in the potato in the presence of *H. schachtii*. Although the nature of these is unknown it seems probable that they operate by producing conditions unsuitable for plant growth, and thus checking the compensatory output of secondary roots, and preventing the plant from overcoming the preliminary set-back in growth resulting from eelworm attack.

It has been established that excess of root excretions of potato and mustard exercise no retarding effect on the growth of potatoes in good soil, but their effects in the presence of the nematode require further investigation.

Histological changes differing only in minor respects from those described for sugar beet, are found to occur in potato roots as a response to the presence of the parasite, while similar changes also occur in the mangold.

A fungus parasite, not yet diagnosed, has been found to be associated with *H. schachtii* in certain soils. This is thought to be of possible significance in the production of disease symptoms.

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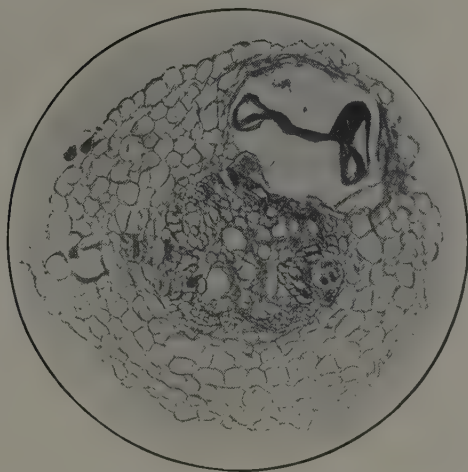
Fig. 1.—Potato Root. Shewing mechanical damage caused by development of nematodes in the tissues.
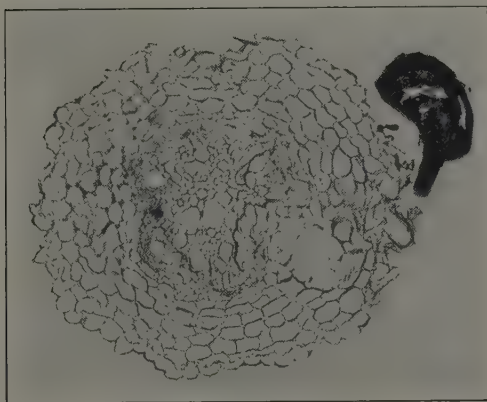
Fig. 2.—Potato Root. Shewing groups of giant cells in the parenchyma and extending into the steele.   *Fungal hyphæ* extend through the giant cells of the parenchyma.
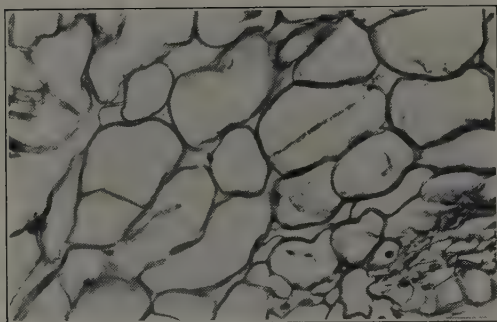
Fig. 3.—Potato Root. Shewing *Fungal hyphæ* extending through normal cells of the parenchyma.
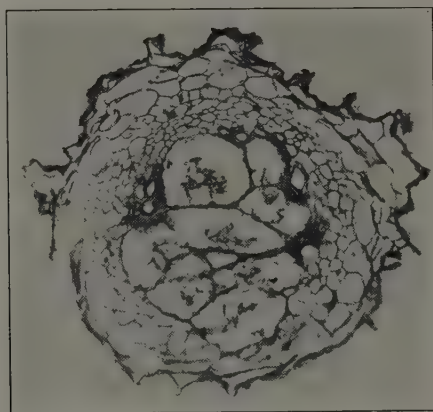
Fig. 4.—Mangold Root. Shewing almost complete suppression of steele by encroachment of giant cells.

Leaf-blotch in *Verbena venosa* caused by *Aphelenchus ritzemabosi*.

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Aphelenchus ritzemabosi is known as a serious parasite of greenhouse plants such as chrysanthemums and gloxinias but the number of records of its attacks on plants grown out of doors is increasing. Disease due to it has been observed in the open on chrysanthemums and dahlias in this country and in the present paper a new out-of-door host is added to the list of plants attacked by it.

On November 8th, 1930, the writer received from Mr. A. S. Buckhurst of the Ministry of Agriculture Plant Pathological Laboratory, Harpenden, some leaves of *Verbena venosa*, showing sharply defined blotches, taken from plants growing in his garden at Harpenden. He had collected them thinking they were attacked by a blotch-producing fungus. On making a microscopic examination, however, no fungus was found, but numbers of small nematodes were present in the affected areas, which he concluded belonged to the genus *Aphelenchus*, the species *ritzemabosi* being suspected. The leaves were submitted for the determination of this question.

Plants bearing blotched leaves were soon obtained from Mr. Buckhurst and from two other gardens in Harpenden, namely Mr. R. Stenton's and from the writer's. One plant from the latter had its lower leaves extensively diseased with large spreading dark areas. These plants had been given to the writer as seedlings by Mr. Stenton in whose garden they were raised.

All the plants involved from the three widely separated gardens were raised from a single packet of seed which had been shared by Mr. Buckhurst and Mr. Stenton. Each had grown his own seedlings separately

and for this reason we cannot account for the occurrence of the affected plants on the supposition that they had been distributed to the three gardens concerned from a single and common stock of infected seedlings. The occurrence of the diseased plants is, in fact, rather difficult to account for except on the assumption that the nematode *Aphelenchus ritzemabosi* is present in the three gardens where the plants were taken, or that the seed, as sown, carried the parasite on it or in it, in a resting condition. As far as the writer is aware, however, there are no published records which indicate that *A. ritzemabosi* can be carried in or upon dry seeds. On the other hand, we know that *Tylenchus dipsaci* can be dispersed by means of seeds, both upon and within the seed coats, consequently the possibility of such a method of spread cannot be entirely ruled out in the case of *A. ritzemabosi*.

The appearance of two infected leaves is shown in figs. 1 and 2. In the lightly affected one the blotches are small and are irregularly scattered over the surface of the leaf. Each dark area is sharply defined and is apparently delimited by the venation of the leaf. It has a brownish or blackish purple colour on the upper leaf surface whilst on the under surface each area has a light brown colour. In the more extensively diseased leaf, the larger blotches overspread major and minor leaf veins, whilst around several of them there is a diffuse discoloration, represented in the drawing by stippling, which is seen on the upper but not on the lower surface of the leaf.

The general health of the plants bearing the diseased leaves did not seem to be adversely affected, for they were as tall and as vigorous as those quite close to them which were free from blotched leaves, at any in the writer's garden.

The leaves of this species of Verbena are firm and stiff and are abundantly covered with short bristly hairs on the upper and lower leaf surface. The appearance of the more lightly diseased leaves recalls, on the whole, that of blotched fern leaves which also are firm and stiff. On the other hand the leaves of chrysanthemums and begonias are of a softer and sappier texture and in these we get a more general discoloration and decay set up by the invading Aphelenchi.

The same is true of the attack on the sappy leaves of the dahlia in which, as Goffart's coloured plate shows, the initial stage of the attack produces extensive yellow areas on the leaf, followed later by brown discoloration and shrivelling at the edges and tip. The texture of a leaf may therefore very largely determine the nature and appearance of the damage caused by these parasites.

Transverse sections across a blotch show that the cells of the epidermis of the upper surface are filled with a purple sap whilst the underlying palisade layer and the mesophyll are discoloured a light greenish brown. The contents of the palisade cells have a very granular appearance and many of the mesophyll cells are collapsed and are coloured brown.
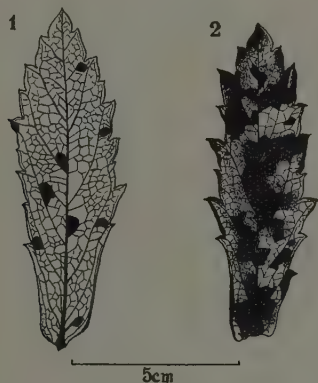
Figs. 1 and 2.—Drawings of upper surface of two leaves of *Verbena venosa*, showing blotches due to *Aphelenchus ritzemabosi* ; 1, lightly, 2, extensively affected, half natural size.

Adult Aphelenchus of both sexes were obtained by teasing up diseased areas in water. The females measured from 0·9 mm. to 1 mm., and the males 0·85 mm. to 0·95 mm. in length. They had the appearance and structure of adult specimens of *Aphelenchus ritzemabosi* obtained from diseased chrysanthemum leaves. The male tail was strongly flexed ventrally, when examples were killed by heat, had the same arrangement of caudal papillæ and spicules of the same shape and size as those of *A. ritzemabosi, vide* Goodey (1928).

Goffart (1930), in his recent work on plant-parasitic Aphelenchi, lists the following plants as liable to attack from *A. ritzemabosi* :—*Chrysanthemum indicum* and *sinense*, Europe, North America and South Africa ; *Rudbeckia sp ?* Germany ; *Dahlia*, Germany (also found at Harpenden, England, September, 1930) ; *Senecio vulgaris*, common groundsel, England, mentioned by Stewart, 1921 ; *Phlox drummondi*, U.S.A., Steiner, 1924 ; *Callistephus*, china aster, Germany ; *Calceolaria* and *Gloxinia*, Denmark, 1928-29 ; *Doronicum* and *Adenostyles alpina*, Germany, 1929.   To these must now be added *Verbena venosa*.

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On the Arthropod Intermediate Hosts of *Hymenolepis diminuta* (Rudolphi 1819).

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Introduction.

Hymenolepis diminuta (Rudolphi, 1819), a normal inhabitant of the small intestine of the rat and other rodents and occasionally to be found in man, has received attention from several investigators desirous of contributing knowledge towards the life history of this cestode. As a result of these researches it is now a well established fact that several arthropods belonging to the Lepidoptera, Dermaptera, Coleoptera, Siphonaptera and Myriapoda can function as intermediate hosts although this wide range of vectors is somewhat unusual.

Within recent years Joyeux (1920) has investigated the life history of this species in detail providing valuable information on the history, habitat and biology of the worm and giving an extended account of the development. He confirmed the early work of Grassi and Rovelli, who first established in 1888 the existence of an insect vector for this tapeworm, and proceeded to feed experimentally other insects to discover new intermediate hosts or to confirm others already cited as such by previous workers.

Work still more recent than that of Joyeux's has added to the list of arthropod vectors compiled by that investigator and at the present time the arthropods which have been found to act, habitually or experimentally, as intermediate hosts or which have, on examination, been found to harbour cysticercoids of this species have reached the number of twenty-three.

In this paper the experimental feeding of fleas, thereby establishing

a new insect intermediate host, is set forth and a brief review of the already known arthropod vectors, together with notes on each, has also been inserted.

EXPERIMENTS WITH *Ceratophyllus wickhami* BAKER.

While research work was being done on the life history of another rat parasite it was seen that several of the rodents were infested with adults of *Hymenolepis diminuta.* With such a supply of fresh material available it was decided to attempt the development of cysticercoids in the squirrel flea (*Ceratophyllus wickhami* Baker). Quantities of larvæ of this flea were very kindly procured by Dr. P. A. Buxton for the writer from the Department of Entomology at the London School of Hygiene and Tropical Medicine. Repeated examinations of specimens demonstrated that the flea larvæ were not infested helminthologically.

The feeding experiments were carried out in the following manner. Gravid segments of *H. diminuta*, procured from the intestines of recently killed rats, were teased up and the ova placed with a very small quantity of fæces from the rectum of an infested rat. To this was added a pinch of pulverised dried rabbit's blood and the whole mixed into a paste of fairly stiff consistency. Portions of this mixture were then placed in short but wide collecting tubes and about twenty flea larvæ introduced into each by means of a fine brush. A disc of butter muslin held in position by an elastic band acted as a covering to prevent the escape of any adult fleas which should complete their metamorphosis. The tubes containing the larvæ and infective food material were then placed in a desiccator over a mixture of sulphuric acid and water in such a proportion as to maintain a relative humidity of about 80, suitable for the development of the flea larvæ. The desiccator was kept in a dark cupboard at laboratory temperature. Under these conditions feeding of the larvæ was noticed and in due course they pupated and eventually became adults.

In his researches Joyeux (1920) found that from 15 to 20 days were sufficient for the formation of the cysticercoid in the intermediate host. Bearing this in mind examination of the adults of *Ceratophyllus* was made when three weeks had elapsed from the time the flea larvæ were introduced beside their food material. On dissection of adult fleas in

a drop of physiological saline solution those which had become infested were easily recognisable since the cysticercoids, lying free within the body cavity of the host, became liberated and appeared in the saline solution. So far as could be observed there appeared to be no reaction on the part of the insect host the tissues and organs presenting a perfectly normal appearance. That not all the fleas were infested was explained by the fact that some of the larvæ, when introduced beside the infective food, were already in their final larval instar and preparing for pupation and refused to feed since cocoons were observed shortly after the experiment was started. The number of cysticercoids per infected flea varied from one up to six, two and three being most commonly found.

This record of a new intermediate host for *Hymenolepis diminuta* is of interest solely from the experimental viewpoint as it is extremely improbable that *Ceratophyllus wickhami*, a flea of *Sciurus carolinensis* the North American Grey Squirrel, could become infested in nature. It does, however, indicate that fleas are easily capable of infection expecially those of the genus *Ceratophyllus* since this is the second species known to act as an intermediate host.

The Arthropod Intermediate Hosts of

Hymenolepis diminuta.

As has been previously stated some twenty-three arthropods are known to act as vectors for this cestode. It has been considered advisable to enumerate them here and to make the list as complete as possible up to the time of writing. Some are only capable of becoming infected in the larval stage, others only as imagos, while a few have been found infected in more than one stage of their life history. Appropriate notes, where available have therefore been added in this and other connections.

MYRIAPODA.

(a) *Fontaria virginiensis* (Drury, 1770) (*virginica* Bollman).

Nickerson (1911) demonstrated cysticercoids in the body cavity of this host in America.

(b) *Julus* sp.

Along with the preceding record Nickerson found the cysticercoids of *H. diminuta* in the body cavity of this host.

INSECTA.

ORTHOPTERA.

Blattidæ.

Three members of the Blattidæ have been cited by Stiles and Hassall (1926) and Faust (1930) as capable of acting as intermediate hosts. There appears to be a certain element of doubt attached to these records as they are not only unsupported by references but other investigators definitely state that their attempts to produce infestation have been quite unsuccessful. Chandler (1922) states that " various attempts to infect cockroaches, including a number of attempts that I have made to feed both the American roach (*Periplaneta americana*) and the croton bug (*Blattella germanica*), have failed." Joyeux also was unsuccessful in producing infestation in *Blatta orientalis* and *Blattella germanica*. Hall (1929) in his recent list does not quote any cockroach as serving as a vector. Moreover, Stiles and Hassall (1928) in their later publication do not refer to any of the three species in question as acting as intermediate hosts for *Hymenolepis diminuta*. Under these circumstances the writer considers it advisable to disregard members of the Blattidæ as vectors until some definite proof of their capability of becoming infested is forthcoming. The three species which have been the subject of experiments are given below.

(a) *Blatta (Periplaneta) orientalis* Linn., 1758.

Cited by Stiles and Hassall (1926) as an intermediate host. Joyeux (1920) was unable to produce positive results with any stages of this insect.

(b) *Blattella (Phyllodromia ; Ectobia ; Blatta) germanica* (Linn., 1767).

Cited by Stiles and Hassall (1926) and Faust (1930) as a vector. Both Joyeux (1920) and Chandler (1922) attempted unsuccessfully to infect this insect.

(c) *Periplaneta (Blatta) americana* (Linn., 1758).

Cited by Faust (1930) as a vector but Chandler (1922) tried unsuccessfully to infect this cockroach.

DERMAPTERA.

(a) *Anisolabis annulipes* Lucas, 1847.

Grassi and Rovelli found this " earwig " to harbour cysticercoids of *H. diminuta*. Infection is stated as occurring in both nymphal and adult stages. Since it seldom comes into contact with or frequents the normal habitat of the definitive host it must be looked upon as being only an occasional vector.

LEPIDOPTERA.

Tineidæ.

(a) *Tinea granella* Linn., 1758.

Cited by Hongo (1922 ; 1925) as an intermediate host.

(b) *Tinea pellionella* Linn., 1775.

Cited by Hongo (1925) as an intermediate host.

Pyralidæ.

(c) *Aglossa dimidiata* (Haworth, 1802).

Cited by Hongo (1922 ; 1925) as a vector in the larval and imaginal stages.

(d) *Aphornia* (*Paralipsa*) *gularis* (Zeller, 1877).

Cited by Hongo (1922 ; 1925) as an intermediate host.

(e) *Pyralis* (*Asopia*) *farinalis* Linn., 1758.

Cysticercoids were found by Grassi and Rovelli in the fat tissue of both larva and imago while Hongo (1922) found the larva, pupa and adult to be infested. This member of the Pyralidæ, commonly found in cereals, flour, meal, clover and hay, easily comes into contact with rodents and may be looked upon as an habitual vector. It seems probable that the pupæ and imagines found harbouring cysticercoids by Grassi and Rovelli, and Hongo acquired the infection in the cater-pillar stage. Joyeux (1920) discusses this and points out that, as a result of experiments carried out by him, the adult moths were found to feed on liquid food only. Moreover, the lumen of the sucking proboscis is of such a small calibre that the eggs of *Hymenolepis diminuta*, owing to their greater size, could not easily, if at all, pass up. His conclusion also is that infestation, founded on these two observations, would seem to be impossible in the imaginal stage.

SIPHONAPTERA.

Leptopsyllidæ.

(a) *Leptopsylla musculi* Dugès, 1832.

Johnston (1913) was unable to demonstrate the cysticercoids of *H. diminuta* in this flea. Joyeux (1920), on the other hand, was able to infect the flea as easily, experimentally, as the other species with which he worked.

Ceratophyllidæ.

(b) *Ceratophyllus fasciatus* (Bosc, 1801).

Nicoll and Minchin (1910) reported this flea as being an intermediate host and Joyeux (1920) also records that young flea larvæ were easily infected experimentally ; older larvæ, preparing to pupate, refrained from feeding and therefore did not acquire infection. Johnston (1913) also found cysticercoids in this species. It is generally considered as an habitual vector.

(c) *Ceratophyllus wickhami* (Baker, 1895).

This flea was found capable by the writer (this paper) of becoming infected and therefore able to act as vector. Younger larvæ only were found to feed upon the eggs of the tapeworm. Owing to its habitat and also to the fact that infestation was produced experimentally this flea cannot be considered a normal and habitual vector.

Pulicidæ.

(d) *Ctenocephalus canis* Curtis, 1826.

Joyeux (1916) showed that the larvæ of this species were capable of becoming infected but he considers it only as an occasional host.

(e) *Pulex irritans* Linn., 1758.

This flea is not an habitual host although Joyeux (1916) found cysticercoids capable of developing in this species the larvæ only being susceptible to infection.

(f) *Xenopsylla cheopis* Rothschild, 1903.

Johnston (1913) discovered infection to occur in this species and later Joyeux (1916) demonstrated infection capable only in the larval stage. The flea is considered as an habitual vector.

COLEOPTERA.

Dermestidæ.

(a) *Dermestes peruvianus* Castelnau.

According to Bacigalupo (1920B) only the larval stage of this beetle serves as an habitual intermediate host.

Scarabæidæ.

(b) *Geotrupes sylvaticus* Panzer, 1795.

Joyeux (1920) found, by experiment, this insect capable of acting as an intermediate host. It is readily infested experimentally as an adult but as it is not commonly available as food for rodents it therefore cannot be considered a normal intermediate host.

Tenebrionidæ.

(c) *Akis spinosa* Linn., 1764.

Grassi and Rovelli found this insect capable of acting as an intermediate host in the adult stage.

(d) *Scaurus striatus* Fabr., 1792.

Grassi and Rovelli also found this beetle to be a vector in the adult stage.

(e) *Tenebrio molitor* Linn., 1758.

Joyeux (1916) found this insect capable of acting as an intermediate host in the adult stage. The larva or common " meal-worm " he ascertained experimentally was incapable of becoming infected. Nickerson (1911) had the same experiences. The present writer also attempted to develop cysticercoids in *T. molitor* larvæ but the results were entirely negative.

(f) *Tribolium castaneum* Hbst. (*ferrugineum* Fabr., 1787).

Cited by Hongo (1922 ; 1925) as acting as a vector.

(g) *Ulosonia parvicornis* Fairmaire, 1892.

Bacigalupo (1929A) found the adults of this beetle to be naturally infested and he considers it a normal vector. Larvæ which were collected and examined were found to be uninfected.

UNDETERMINED INSECTS.

Hongo (1922) records as vectors five species referred to above and also four species of undetermined insect larvæ. In a later paper, however, in 1925 he gives six specifically named hosts and reduces the number of species unidentified to two insects.

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Observations on the Tropisms of *Dorylaimus saprophilus* and *Rhabditis succaris.*

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UP to the present time, free-living Nematodes have been considered mainly from the systematic point of view. In respect of numbers, of both individuals and species, they probably rival the insects more closely than any other group of the animal kingdom. They are extremely abundant, being found in every kind of habitat in large numbers and new species are being recorded constantly. It is natural, therefore, that diagnosis and classification should have assumed an important aspect. But the physiology and bionomics of free-living eelworms prove themselves to be both interesting and complex. In the following pages is given an account of some experiments which have been carried out on two free-living Nematodes. The object of these experiments was to work out what reactions, if any, were produced by various common physical and chemical stimuli. Some notice was first taken of the reactions under ordinary conditions of life so that true comparisons might be drawn.

Dorylaimus saprophilus and *Rhabditis succaris* were the medium chosen for these experiments. *Dorylaimus* was chosen partly on account of its large size ; this was useful because the microscope was not needed for observation. This species has, however, proved difficult to cultivate and breed in the laboratory and hence when particularly large numbers of a worm were needed for an experiment a thriving culture of *Rhabditis* was used. This species lives and breeds well in a watery medium when provided with suitable food. *Dorylaimus* was found originally as part of the fauna of a sewage farm. It appeared quite suddenly about two years ago and since then has become established there. It is, however, very narrowly adjusted to its surroundings, and when the material is

removed to Petri dishes in the laboratory, the *Dorylaimus* die within a few days and very few specimens can be discovered after seven or eight days. They live normally in the zoogloeal film round the clinker and when they find themselves in fluid they are obviously out of their element. Under these conditions they are sluggish, executing slow movements and lying for long periods without any sign of life. The worms are easily stimulated and show the typical Nematode movement when touched with a needle, when more fluid is added to the dish or when they are transferred from one vessel to another. The effect of this stimulus soon wears off and after repeated stimulation they cease to react. They remain alive, however, for four or five days, but finally die by drowning. The best way of keeping a stock of *Dorylaimus* was found to be in a semi-solid medium.

A culture of snails has been living in the laboratory for some time and the liquor in which they live is full of small green organisms besides Protozoa and Bacteria, and in solution there is a varying amount of chlorophyll, derived in large part probably from the fæcal matter of the snails. This gives the liquor a characteristic green colour. This fluid, when filtered to get rid of the large particles, was used with agar agar to make up gelatine plates in Petri dishes, and these proved to be useful in keeping *Dorylaimus* alive for considerable periods of time.

The *Dorylaimus* were removed from the freshly gathered clinker and placed on the surface of these plates, and within a minute or so they had bored their way into the plate. This particular species does not behave as most eelworms do, for in fluid it is a remarkably sluggish organism but on an agar plate it becomes active and after a few days the plates are riddled with meandering channels. Hence, as Looss demonstrated for hookworm larvæ, this Nematode can have a definite progressive movement when the medium gives it the necessary purchase. These channels are made by sheer muscular activity and the stylet plays no part whatever.   The worms move equally well in either direction. They lie immobile for long periods in the jelly but if they are stimulated by the touch of a needle they immediately show an active sinuous movement away from the point of stimulation, and according to whether the stimulus is given at the head or the tail, so is the direction of movement either backwards or forwards respectively.

In this medium they have remained alive for several weeks ; this is a considerable advance on the four or five days that they have remained alive in water. What is more important is that they do not become senile so readily on agar.

Whenever possible the worms were taken directly from their natural habitat but on one occasion,when they were showing a curious periodicity worms taken from stock were used and these showed little, if any, decrease in metabolism or activity. This periodicity was interesting in showing how very narrowly adjusted the worms are to their habitat —for six or seven weeks the rainfall had been negligible and hence the sewage had become more concentrated than usual. The worms could not withstand the increased toxicity and for several weeks none could be found. When rain began to fall in any quantity, young immature forms were found in abundance and within a fortnight or three weeks adult worms were visible in as great numbers as before.

The inactivity in a fluid medium and the rapidity with which death intervenes suggests very strongly that *Dorylaimus* is normally a soil inhabiting form which has but recently adapted itself to life on the filter beds. Experiments are now in progress to discover the optimum conditions for breeding. While *Dorylaimus* seems to be a semi-terrestrial form, *Rhabditis* is a typical aquatic Nematode. In water it is in constant movement, but there is no direction in its movements, and unlike *Dorylaimus* on agar plates, it does not progress. At times, however, *Rhabditis* becomes lethargic and falls to the bottom of the dish ; here they lie quite still in ungraceful attitudes. Occasionally they show a jerky movement of the head or the tail or sometimes there is a slow movement resulting in a slight change of position. This lethargic state may be an indication of approaching senility for in many cases the cuticle begins to crinkle and though they have been observed at frequent intervals for four or five hours, they have seldom become activated again. Florence Payne has pointed out that hookworm larvæ have alternating periods of activity and rest and in the latter state has shown that they will not react to stimuli. In hookworm, however, this quiescent phase rarely lasts for more than 30 minutes, when they emerge to the fully active state. The writer has observed comparatively few cases where the eelworms have become active again.

Dead *Rhabditis* can easily be distinguished from either living or dormant ones as they float on the surface of the fluid and lie either very straight or in a curiously angular position. In either case the fat globules in the intestine tend to run together, the cuticle swells up and bacterial invasion sets in rapidly.

REACTIONS TO VARIOUS PHYSICAL AND CHEMICAL STIMULI.

Fülleborn quotes the definition of a Tropism given by Przibram (1913) —" Die Bewegung eines Tieres in einer bestimmten Richtung unter den Einfluss eines ' richtungsgebenden Reizes ' verstehen '' The worms mentioned above, were brought under the influence of certain common stimuli—for example, light, changes of temperature, etc., and their tropic responses, if any, noted.

Hydrotropism.

As Clayton Lane has already pointed out, there can be no hydrotropic reaction. *Dorylaimus*, though not aquatic, normally lives in a film of water round solid particles and dies if removed to a dry atmosphere. Therefore it cannot be said to be affected by any other body of water, external to it.

Thermotropism.

These eelworms are able to live within a fairly wide range of temperatures. At low temperatures they become dormant but are not killed unless they are actually frozen.

Some *Dorylaimus* were placed in a watch glass in water and the whole frozen for ten minutes. When the block was thawed, the worms were all dead. Examined under the microscope, small lesions were visible in the cuticle—tiny areas, scattered over the surface, were raised up from the underlying musculature forming small blisters. These might have been caused by the penetration of the ice crystals. No other pathological changes were to be observed in the worms. Worms were subjected to low temperatures of varying severity and a high percentage always revived when warmed up, even when the surface of the pool had frozen over. The lower the temperatures, the longer was the time taken for them to become active again.

For instance, at 0° C. when the surface froze, the worms revived but slowly, taking about 30 minutes to become reactivated ; 35 per cent. were dead. At 4° C. they became dormant in 5 minutes ; 85 per cent.

revived within 10 minutes. At 8° C. they became dormant in 12 minutes ; 100 per cent. revived within 5 minutes. When left at 4° C. for 3 hours they became active again almost as soon as the watch glass reached laboratory temperature—that is to say in about 7 to 10 minutes and the first sluggish movements were observed within two minutes after removal from the refrigerator.

Similar results were obtained with *Rhabditis*, but these worms revived in a much shorter space of time and were extremely active again within three minutes.

The activity of the worms increases with increasing temperature, and this is obvious, whether they are in a film of water on a slide or in a deep pool. Khalil's experiment with a floating cover glass was repeated with *Dorylaimus*, but though they became increasingly active, the heat applied had no directive stimulus. As the worms were too heavy to be carried by the strong convection currents that were seen in the dish, they remained at the bottom.

The reaction of *Dorylaimus* lying on an agar plate was interesting. One side of the dish was heated considerably, so that a small area of the gelatine actually melted. The heat was therefore intense and many worms in the neighbourhood were killed. Others, which were further away, exhibited a strong negatively thermotropic response, and they moved, with considerable speed, in a straight line, away from the source of heat. The speed of several worms was measured across a large Petri dish about 9 cms. in diameter ; the average worked out at about 1 meter per hour, being well over 1·5 cms. per minute. This is considerably less than Fülleborn's result with Strongyloides (5·2 m. per hour), but is much greater than the result with hookworm larvæ (3 ins. per hour).

For a very long time it has been known that infective hookworm larvæ are positively thermotropic and use has been made of this fact in extracting them from the soil, by means of the Baermann apparatus. The writer has often attempted to extract the Nematodes from the sewage by similar means, but has met with poor results. Some species have appeared well, but only a small percentage of the *Dorylaimus* have been extracted. The cause of this is now obvious as the worms show no tropic response to sub-lethal temperatures, but only an increased activity.

The worms cannot stand heating above 30°C.   Above that temperature the protoplasm coagulates and they die.

Geotropism.

As has been previously noted *Dorylaimus*, when placed on an agar plate, immediately bores its way into the medium and often takes up a position on the floor of the dish underneath the gelatine.   This led the writer to consider the possibility of a positive geotropism ; 25 worms were therefore placed on the surface of a thin agar plate, and 24 hours later all had bored their way into the medium.   The dish was then inverted and they tended to bore their way back again, but only two actually reached the surface ; the others remained in the jelly.

Later a square cornered dish was used ; the sides, but not the floor, of this were covered with a layer of the gelatine and worms placed in the dish.   Though these worms were first placed near the agar and later actually in contact with it, only 5 out of 25 attempted to bore and the rest sank to the bottom of the dish and lay in the water.   In another experiment several turrets of agar were placed in the middle of a deep dish forming islands in the water, the sides and floor being bare ; 25 worms were added.   After 24 hours all were lying in the angles formed by the floor and the sides of the dish.   When removed to the tops of the turrets they reacted normally and bored their way down.

A surprising result was obvious on one occasion when worms had, as usual, been placed on an agar plate.   Instead of all boring into the jelly a few had climbed the sides of the dish, had dried and were therefore dead. Whenever this experiment was repeated afterwards, this same result was obtained.   These worms had therefore moved directly against gravity, and hence show that the instinct to bore into the semi-solid medium is not in response to a gravitational stimulus.

A very thick plate, about an inch thick, was made for the worms.   The bulk of them entered, as usual, but they were content to remain in the upper layers and only occasionally could one be seen which had passed right through in its wanderings.   The upper region of the plate was, however, riddled with their channels, while deeper down there were very few.

Stereotropism.

The discordant results, described in the last paragraph, lead one to the view that this burrowing instinct is not due to a positive geotropic response but is rather the result of a stereotropic stimulus. The need to place as much as possible of their body surface in contact with a solid medium is filled when they burrow into an agar plate, and to a less extent, when they climb the sides of the dish, but in the latter case the reaction leads to death by dessication. Stereotropism would also explain why, in water, the worms are always found in the angles formed by the sides and floor of the dish, for there only can they feel anything solid.

Heliotropism.

Both *Dorylaimus* and *Rhabditis* were used to test the action of light. To consider *Dorylaimus* first. An agar plate was made from snail liquor. Half of the Petri dish was then covered with black paper, thus excluding all light from that half, and 25 worms were placed along the line of division of the two halves. Next day two were in the light half and the rest had migrated to the dark half. The light and dark portions were then reversed so that what had originally been light was now dark, and vice versa. The worms were active and by the following morning the jelly was full of intersecting channels. But out of the 25 worms 22 had found their way into the darkened portion. This result strongly suggested a negative heliotropic response, and the writer called to mind that the culturing of *Rhabditis succaris* had proceeded with far greater ease in the dark than in the light.

A thriving and healthy culture of *Rhabditis* was therefore subjected to the conditions described above ; one-half of the dish being darkened and the other left in the sunlight. When examined a few hours later with a dissecting microscope, the worms in the light half were seen to be lying dormant and moribund at the bottom of the dish, and they never recovered. The others were quite healthy.

An attempt was made later to cultivate them in such a dish, and the same result was obvious. Of those that were subjected to bright light very few were capable of depositing eggs and the larvæ thus hatched never grew to adulthood.

In both these experiments there was no question of a negative helio-tropism. Instead, either certain rays forming white light, or else the

ultra-violet rays, appear to have a lethal or narcotic effect on the worms, so that their activities are inhibited and they lie at the bottom of the dish until death finally supervenes. That ultra-violet in large quantities is lethal to animal tissues is well known and irradiation with ultra-violet, followed by dry heat or infra-red irradiation, has been shown to have rapid lethal effects at all temperatures on *Demodex folliculorum*. Probably some similar effect is made upon the delicate bodies of the eelworms, but experiments are under way to discover which rays in particular are responsible for this lethal effect.

Chemotropism.

Many Protozoa and spermatozoa have been shown to have strong chemotropic responses, and the writer considered the possibility of such a solution to the problem of the boring of *Dorylaimus*, especially as the worms refused to bore into a nutrient agar plate made with meat extract. The method of capillary tubes, introduced by Pfeffer and adopted by Loeb, was used here. Solutions of known dilutions of the substances to be examined, are made up and a capillary tube of known bore is filled with the solution. One end is then sealed and the tube placed in the dish with the worms. The capillary tube used here had a width of 0·1 mm., or sometimes rather less, and the length was 15 mm. From this capillary, diffusion is extremely slow and in an approximately straight line. The dish used had a flat floor. For each experiment some 25 *Dorylaimus* were used. The substances tested were very varied, in an attempt to cover some of the most important chemical groupings ; the dilutions were 1 in 100, 1,000, 10,000, 100,000 of each substance—*i.e.*, the percentages were 1, 0·1, 0·01, 0·001. Ten substances were used in the concentrations mentioned above, but remarkably little data was obtained. The results are summarised in the accompanying table.

Of the two substances used in the production of the plate, the snail liquor was without any effect on the eelworms, while agar agar was positive down to a dilution of 0·01 per cent. Amongst inorganic compounds the hydroxides tended to have a negative effect while sodium hydroxide—NaOH—was definitely lethal in 1 per cent. solution. Butyl alcohol and Thymol were also negative in 1 per cent. solutions, but had no action in greater dilutions. The only positive results were obtained among organic compounds. Agar agar has already been mentioned ;

lactic acid and lactose gave positive results in 1 per cent. and 0·1 per cent. solutions and sodium citrate tended to be positive.

Though these results are described as positive or negative, yet they were in no sense clear cut.   *Dorylaimus* is of course far too big to

					1%	0·1%	0·01%	0·001%
Sodium hydroxide	...	...	...	...	lethal	—	0	0
Ammonium hydroxide		...	...	...	—	0	0	0
Hydrochloric acid	...	...	...	...	0	0	0	0
Butyl alcohol	...	...	...	...	—	0	0	0
Sodium citrate	...	...	...	...	+	0	0	0
Lactic acid	...	...	...	...	+	+	0	0
Lactose	...	...	...	...	+	+	0	0
Thymol	...	...	...	...	—	0	0	0
Agar	...	...	...	...	solid	+	+	0
Snail liquor	...	...	...	...	0	0	0	0

0 no definite result obtained.   — negative.   + positive.

enter a capillary tube, but only in the case of agar 0·01 per cent. solution were they ever seen clustered round the aperture.   Results are described as positive when over 60 per cent. of the worms had moved until they were in the direct line of diffusion and not too far away.   Other results are described as indefinite and are shown by " 0 " in the table.

Conclusions.

The only conclusion to be drawn from these results is that the burrowing habit of *Dorylaimus* into agar plates is to be explained by a combination of several tropic responses, of which the strongest is undoubtedly a stereotropism.   A negative heliotropism and a positive chemotropism (with regard to agar agar) may play some part.   The worms, however, demonstrate no strong tropic responses.   Its habit of living within the thick zoogloeal film is probably to be explained mainly as a stereotropic response though nutritional factors may have a part also.

Summary.

(1) The reactions of *Dorylaimus* under ordinary conditions of life are noted, especially its mode of progression and its burrowing habit.

(2) Some experiments were carried out with a view to finding out what physical and chemical stimuli are responsible for bringing about these reactions.

(3) The possibility of hydrotropism, thermotropism, geotropism, stereotropism, heliotropism and chemotropism are considered.

(4) The conclusion to be drawn from the data is, that taken on the whole, eelworms do not exhibit well marked tropic responses except in the case of stereotropism. It is obvious here, however, that they do everything in their power to put their body surface in contact with some solid object. This need explains why the worms are always found in the interstices of the zoogloeal film round the clinker. No other tropic response is needed to explain this habitat.

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On the occurrence of *Hepaticola hepatica* as a natural infection of the Wild Rabbit in England.

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IN the experiments carried out by Nishigori (1925) and Saito (1925) on the life-history of *Hepaticola hepatica* it was shewn that this parasite does not reach maturity when a rabbit is artificially infected with embryonated eggs. It is true that the worms shewed some development, but after a time they disappeared leaving only nodules of connective tissue. In view of these results it may be of interest to record a case, observed by the writer where a rabbit carried a natural infection.

A dead rabbit brought to the Laboratory by Dr. G. M. Vevers shewed, on examination, a good deal of congestion in the liver while on the surface of this organ appeared many whitish or yellowish irregular patches. These areas, on cursory examination suggested coccidiosis but proved on closer inspection to contain masses of nematode eggs of the type usually associated with the members of the Trichocephalidæ. Portions of female worms were also teased out and these were also surrounded by large numbers of eggs. No males were, however, found and a complete study of the worm could not, therefore, be made, but the character of the eggs showed, with little doubt, that the parasite could be referred to *Hepaticola hepatica.*

Another record of the occurrence of worms in the liver of a rabbit is that by G. Generali (1878). The writer has not been able to consult the original paper in this connection but according to Hall (1916) this author " notes the finding of encysted filiform nematodes in the liver of a rabbit, causing nodules resembling those of coccidiosis and associated with coccidiosis." This would appear to be a case of *H. hepatica.*

Troisier and Deschiens (1930) mention its occurrence in the rabbit in France on the authority of Lebert.

Nicoll (1911) records the occurrence of worms in the liver of a hare (*Lepus europæus*) and from a study of the eggs and fragments of the female he concluded that the worm belonged to the Trichosoma group. Hall (1916) tentatively refers this worm found by Nicoll to *H. hepatica*, his doubt being based on the assumption that it would be more often found if it were a common parasite of the rabbit.   He also refers to the discrepancies which occur between the structure and measurements of the eggs, given by Nicoll, and those found by him, for *H. hepatica*. Nicoll found two types of eggs differing greatly in size ; one being found in the uterus, and the other in the vagina.   The one in the uterus, which may be considered as the normal egg, measured 0·057 mm. by 0·033 mm., which is slightly in excess of the maximum found by Hall, viz., 0·052 mm.   The other type of egg found in the vagina measured 0·070 mm. to 0·078 mm. by 0·040 mm. to 0·045 mm.

It seems evident that a considerable variation exists in the size of the egg of this parasite.   Baylis (1929) as a result of his observations in this connection gives measurements of 0·0625 mm. to 0·0675 mm. by 0·03 mm. to 0·0325 mm.   The eggs found in the liver of a rabbit now recorded gave an average measurement of 0·054 mm. by 0·032 mm.

A few large eggs similar to the ones found by Nicoll in the vagina were also observed by the writer.   Both Nishigori and Saito also refer to this type of egg in infections from the liver of rats.   These latter authors consider these eggs to be degenerative stages of ordinary eggs.

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Experimental Infection of Sheep with *Dicrocœlium* dendriticum.

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FIVE years ago, while on a visit to Glasgow, my attention was drawn by Mr. Peter Braid, M.R.C.V.S., to the occasional appearance of *Dicrocœlium dendriticum* in the liver of sheep from the West of Scotland. Mr. Braid arranged to supply me with such livers as in future came to his notice and to ascertain, where possible, the place of origin of the sheep. In this way, I have received from him livers from sheep which came from Tiree, South Uist, Barra, Harris, Campbelltown, and from Berwickshire, Ayrshire and Lanarkshire. Enquiries locally at these places shewed that some at least were mere markets. In Berwick, for example, sheep were on sale which had come from the West ; and in the West, sheep which had originated in the islands. In the case of the Hebrides, however, sheep are not habitually imported for subsequent re-sale and the great majority—certainly all the young animals—are bred locally. It seemed legitimate to conclude therefore, that in these cases, the disease also was acquired locally. The various islands were visited in autumn, 1929, and Tiree was selected as affording the best and most convenient situation for an investigation into the life-cycle of the parasite.

Two species of land-snails, *Helicella itala* and *Cochlicella acuta* were abundant and these occurred on certain sandy, grass-covered dunes of the island. At another visit early next year they were found to

be present in thousands in these places and were being eaten with the grass by the numerous sheep which fed all over the island. Their distribution was patchy and they occurred only on the poorer grazing areas. In addition to these species only the following were found and in comparatively small numbers in positions where they could be eaten by sheep :—

> *Oxychilus cellaria,*
> *Pyramidula rotundata,*
> *Lauria cylindracea,*
> *Vitrina pellucida.*

A number of specimens of *Helicella* and *Cochlicella* was collected and taken to Edinburgh where they were fed with Dicrocœlium eggs. At the suggestion of Mr. Cyril Diver and Mr. G. C. Robson they were kept on Tiree soil in wooden boxes with gauze sides and provided with artificial dew each evening from a spray. It was found that they would eat blotting paper and slices of carrot. They were accordingly fed with eggs spread on these substances either in Petri dishes or in a box. The snail fæces could be easily collected and examined in the Petri dishes and it was found that a considerable proportion of mature eggs had lost their opercula. They were fed at intervals from the 18th April, 1930, onwards. Snails were examined at various periods, but not until the 23rd June were cercariæ found in any of them. The same species was found on the 21st July, in the same batch of snails. At the end of August, only five snails remained alive ; all of these contained young stages of what appeared to be the same fluke. During the period while these investigations were in progress, two papers appeared in Germany (Nöller, 1929 ; and Vogel, 1929) giving an account of attempts to solve the problem of the source of Dicrocœlium infection by an intensive epidemiological study of certain heavily infected regions in southern Germany.

Nöller found, in several areas where the sheep were heavily infected with Dicrocœlium, that *Zebrina detrita* was parasitised with the *Cercaria vitrina* of von Linstow. The distribution of the trematode, however, did not entirely coincide with that of the snail, and this suggested that, while the cercaria was obviously the larval stage of a Dicrocœlid fluke,

either it was not the cercaria of *Dicrocœlium dendriticum* or Zebrina was not the normal host. A further search for snails showed that not only was *Torquilla frumentum* coincident in its distribution with *Dicrocœlium dendriticum* in the area, but that it also carried the same cercaria. As this species is much smaller, he considered that it was a more probable normal host.

A number of Zebrinas were collected by Nöller from a lightly infected area. 47 of these were fed with the eggs of Dicrocœlium ; 16 were kept at room temperature and the remaining 31 at under 16°. After six months, nine of the former were alive and four were infected with *Cercaria vitrina* ; while all the second group were alive, but only one harboured the cercaria. One snail showed very young stages. Of 226 controls four contained the same cercaria. While these experiments were very suggestive, the finding of cercaria in the controls prevented a definite conclusion.

Vogel found the same species of cercaria in *Helicella candidula* and in *Zebrina detrita* in an area where every sheep harboured Dicrocœlium. About 10 to 20 per cent. of these snails were infected, and only a single Harmostomid cercaria was found in addition to *Cercaria vitrina*. He concluded from the epidemiological evidence as well as from the morphology that this is the larval stage of *Dicrocœlium dendriticum*.

The cercaria obtained by me experimentally in *Helicella itala* appears to be identical with that described by these workers.

In June and July of 1930, I fed the bodies of the snails from which I had removed some of the above cercaria to two sheep for which I am indebted to Mr. W. Miller, M.R.C.V.S., of the Animal Breeding Research Department. These were a year old and had passed their entire life in the University grounds. They were kept in a paddock which had not been used for sheep for some years.

Examinations of the fæces were made from time to time. Towards the end of November, the eggs of *Dicrocœlium* appeared for the first time in the fæces of one of these sheep, proving not only that *Cercaria vitrina* is the larval stage of *Dicrocœlium dendriticum* but also that the mode of infection of sheep is by swallowing the infected snails.

I should like to express my indebtedness to the Imperial Bureau of Agricultural Parasitology for valuable assistance in connection with the literature.

This preliminary note will be followed by a more detailed discussion of the life-cycle and bionomics of the fluke.

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An Observation on Human Resistance to Infection with Ascaris from the Pig.

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THE question as to whether Ascaris from the pig may be transmitted to man, and its converse, have long been recognised as being of considerable public health importance. Hitherto the evidence, both epidemiological and experimental, is somewhat in favour of the belief that human Ascaris and Ascaris from the pig are not interchangeable as to their respective hosts. Experimental evidence in support of this was supplied in 1922 by Koino, who swallowed a large number of embryonated eggs from the pig form, and although severe pneumonic symptoms were set up by the migrating larvæ, the latter did not complete their development, and no intestinal infestation followed. A similar negative result was obtained by Payne, Ackert and Hartman (1925), from infection experiments performed on themselves and on a rhesus monkey ; they also fed large numbers of human Ascaris eggs to pigs but without success. Some epidemiological evidence has also been furnished by these workers, for they indicated that although in Trinidad and Arouca the circumstances were favourable for reciprocal infection, yet the incidence of Ascaris in man and pigs in these regions in no way suggested that such a condition of affairs obtained.

In the above experiments the material employed consisted of embryonated eggs. Recently in this Department an attempt was made by Professor R. T. Leiper and myself to obtain further information on the subject, by using the migrating larvæ instead of eggs. A portion of the lungs of a young pig, which had died some days after receiving a heavy dose of embryonated pig Ascaris eggs, was chopped up finely and large numbers of the migrating larvæ were extracted by means of the Baermann technique. These were washed in normal saline and

about twenty were transferred to a piece of bread and swallowed by me. At the same time much larger numbers were fed to a green monkey and as a control, to two pigs. Up to three months later no indication of infection was found in either of the first two cases but the pigs were found to be harbouring large numbers of adult worms.

This result appears to add weight to the opinion that man is not susceptible to infection by pig Ascaris, and that the monkey is an unfavourable host for it. The work of Hiraishi (1928) however, indicates that an animal's susceptibility to helminth infection may be influenced by its diet, for he succeeded in infecting pigs with human Ascaris which had previously been fed with a diet deficient in vitamin A, while pigs fed on an adequate diet failed to become infected. Although the converse of this experiment would be likely to prove positive and a man suffering from A-avitaminosis might possibly be found to be easily infected with pig Ascaris, yet, since such a condition is an abnormal one, the evidence still remains strong that the human and pig Ascaris belong to two distinct strains.

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Note on a Fungus Parasite associated with *Heterodera schachtii* Infections on Potatoes.

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IT has been, for some time, a recognised fact that intense eelworm infections are, in some instances, accompanied by only slight damage to the plants, while in other areas where the infection is much less intense, the plants show every symptom of " potato sickness " and the crop is a complete failure.

Further, a striking characteristic of infections by *H. schachtii* on this host, is the occurrence of " bad patches " in infected fields, that is, small areas where the plants show dwarfing, yellowing of the foliage and early dying down of the tops, although the major portion of the crop remains apparently unaffected by the presence of the nematodes. Cyst counts made from soil samples of such fields taken both from the bad patches and regions of normal growth have shown that the patchiness is not due to variations in the intensity of infections and differences in the pH values of the soil have not been found. Where prolonged observations on fields showing these small " potato sickness " patches have been carried out, yearly increases in the size of the affected areas have been shown to occur.

This gradual spread of the disease symptoms seems to point rather to a living association between *H. schachtii*, which is undoubtedly one pathogenic factor, and some other organism, than a plant-food deficiency or other soil condition rendering the land unsuited to potato culture.

Two fungus parasites, *Corticium solani* and *Colletotrichum tabificum* have frequently been noted as being commonly associated with *H. schachtii*, and several writers have suggested that their presence as

secondary parasites of plants already suffering from the attack of *H. schachtii* might be the determining agent in the production of disease symptoms. Recently Miles, however, has shown that this is not the case, although *Colletotrichum tabificum* may hasten the death of plants.

The discovery of another species of fungus which invades the root tissues of potatoes grown in certain Lincolnshire soils infected with *H. schachtii* has already been noted by me in a previous publication. This species has since been identified by Mr. Ramsbottom as *Colletotrichum atramentarium* (Berk. and Br.) and is known to produce disease symptoms which cause the early death of potato plants. A full description of the life cycle of the parasite and its effects on the host are given by McAlpine 1911. Its occurrence in association with *H. schachtii* may, therefore, prove to be of some significance in the disease known as " potato sickness," and, as a possible contributory factor this association seems to merit further study.

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The Helminth Parasites of Common Rats.

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INTRODUCTION.

WHILE it is true that various lists of rat parasites have been published these, however, deal only with individual Classes of helminths. Notably amongst such publications are those by Hall (1916) dealing with the Class Nematoda, by Meggitt and Subramanian (1927) who treat of the Class Cestoda and by Dollfus (1925) who reviews the species of the Class Trematoda. It was suggested to me by the Imperial Bureau of Agricultural Parasitology that the collection of notes, records and information concerning the helminth parasites of common rats into one single work would be useful and the information contained in the three compilations mentioned above has been largely drawn on in forming the nucleus of this paper. Other publications, found helpful in providing additional information, are those by Balfour (1922) who deals with the parasites of wild rats in England, Baylis (1922), Cleland (1918), Fielding (1928), Johnston (1918), who summarises the knowledge concerning the parasitism of rodents in Australia, Meggitt (1924), Moll (1917), Shipley (1908), and Yorke and Maplestone (1926). For the more recent records, not included in any of the foregoing publications, the *Vermes* section of *The Zoological Record* and the " Répertoire des Genres nouveaux et des Espèces nouvelles," appearing in each number of the *Annales de Parasitologie humaine et comparée* were consulted advantageously. The checking of many records, at least of the earlier ones, was accomplished by means of Stiles and Hassall's invaluable *Index-Catalogues* (1908, 1912, 1920).

Little need be said here concerning common rats since their economic importance is so widely understood. They have, due to their power of becoming established in widely separated localities and to their prolific breeding habits, invaded and colonised all lands throughout practically the whole world, and while they constitute serious pests damaging property and other materials they also form a grave menace to Public Health. However large may be the financial loss occasioned by rats it is insignificant when the risk of disease due to the presence of these rodents is considered. Plague, Rat-bite Fever, Spirochætal Diseases, Equine Influenza, Foot-and-mouth Disease, together with various helminths are all known to be disseminated by rats. With regard to the last named the rat may act in a dual capacity ; it may act as an intermediate host especially for cestodes for forms of the genus *Tænia*. Of more importance, however, is the rôle played by the rat as a spreader of worms, not only for cestodes but also for nematodes and trematodes. As a spreader the rat may disseminate infection in some cases to man, domesticated or wild animals either directly or indirectly. Indirect infection is usually accomplished when the helminth has, as intermediate host, some form of insect or other arthropod as is the case for certain cestodes and nematodes, or some mollusc such as in the trematodes. The increased recognition of the importance of rats as reservoirs of disease lends additional value to the records concerning their parasites.

The records are confined to the common forms of rats encountered in the various countries of the world and the species dealt with fall into four groups.

Group 1. The Black, House or Ship Rat, *Mus* (*Rattus*) *rattus* Linn., 1766. Synonyms : *Rattus rattus, Epimys rattus.*

Group 2. The Alexandrine Rat which appears to be a variety of the above but is treated on many occasions in host records as a distinct species, *Mus* (*Rattus*) *rattus* var. *alexandrinus* Is. Geoffroy, 1812. Synonyms : *Mus alexandrinus, Rattus alexandrinus, Epimys alexandrinus.*

Group 3. The Common or Brown Rat, *Mus* (*Rattus*) *norvegicus* Erxleben, 1777. Synonyms : *Rattus norvegicus* or *norwegicus, Mus decumanus* (Pallas, 1778), *Epimys norvegicus.*

Group 4. This group can only be conveniently labelled '' Rats ''
as it consists of a collection of various names which may or may not
refer to one or other of the three forms mentioned above. In the liter-
ature consulted such names as the following have been encountered :
'' Wild rats,'' '' Rats,'' '' *Mus* sp.'' in conjunction with '' rat,'' '' Rat
sp.'' with native names following, '' *Rattus* sp.'' and so forth. Remarks
referring to any species of rat not definitely stated to be *Mus* (*Rattus*)
rattus, Mus (*Rattus*) *rattus* var. *alexandrinus* or *Mus* (*Rattus*) *norvegicus*
must therefore be considered with a certain element of doubt since
the name of the host may be only a local or common one given to rodents
which may not be true rats as defined in this paper.

Wherever possible records concerning the location of the parasite
within the host's body have been inserted along with locality records.
The references subjoined to each species indicate the more important
papers concerning the parasite wherein fuller information is contained.
In every case the first reference to a paper given is that in which the
species was first described. In several cases the literature dealing with
a single species was very extensive and has been set forth in other
works. Consequently the number of references given has been limited
to a few of the more important ones in which full bibliographies exist.

The total number of helminths reported in this paper from common
rats is 109, comprised of 27 trematodes, 41 cestodes, 40 nematodes
and 1 acanthocephalid. That every form is a distinct species is open
to doubt as in some cases certain authors consider forms herein listed
should be looked upon as synonyms. Where such is the case appropriate
remarks on this view have been included. Further, about a dozen forms
generally considered now-a-days as invalid or dubious species have been
noted as such although their names still occur in the literature.

From the records the following figures indicate the distribution of
the various helminths in their hosts :—

Total number of parasites reported from—

Mus (*Rattus*) *rattus*	47
Mus (*Rattus*) *rattus* var. *alexandrinus*	15
Mus (*Rattus*) *norvegicus*	69
'' Rats ''	26

Number of parasites reported as occurring only in—

Mus (*Rattus*) *rattus*   15
Mus (*Rattus*) *rattus* var. *alexandrinus*   1
Mus (*Rattus*) *norvegicus*   39
" Rats "   20

Number of parasties common to two or more of the groups of
rats—

Mus (*Rattus*) *rattus* and its variety *alexandrinus*   1
Mus (*Rattus*) *rattus* and *Mus* (*Rattus*) *norvegicus*   14
Mus (*Rattus*) *rattus* and " rats "   2
Mus (*R.*) *rattus, M. rattus* var. *alexandrinus* and *M.*
norvegicus   12
Mus (*R.*) *rattus, M.* (*R.*) *norvegicus* and " rats "   2
In all four groups together   1

TREMATODA.

Order : D I G E N E A v. Beneden, 1858.

Sub-order : *PROSOSTOMATA* Odhner, 1905.

Fam. : *L E P O D E R M A T I D Æ* Odhner, 1910 (=Plagiorchidæ
Lühe, 1901).
Sub-fam. : *LEPODERMATINÆ* Looss, 1899.

Genus : L E P O D E R M A Looss, 1899 (= Plagiorchis Lühe, 1899).

1. LEPODERMA MURIS Tanabe, 1922.
Rat hosts.—*Mus rattus, Mus norvegicus, Mus norvegicus* var. *albus.*
Location.—Small intestine.
Locality.—Japan.
Remarks.—Infection is stated to occur naturally.
References.—Tanabe, 1922B ; Dollfus, 1925, 188.

Fam. : *OPISTHORCHIIDÆ* Lühe, 1901.
Sub-fam. : *OPISTHORCHINÆ* Looss, 1899.

Genus : CLONORCHIS Looss, 1907.

1. CLONORCHIS SINENSIS (Cobbold, 1875) Looss, 1907.
    Rat hosts.—*Mus rattus, Mus norvegicus.*
    Location.—Liver and intestine.
    Locality.—Japan, Korea, China, Formosa, French Indo-China.
    Remarks.—Infection is stated to occur both naturally and experimentally in rats.
    References.—Cobbold, 1875 ; Dollfus, 1925, 188.

Fam. : *HETEROPHYIDÆ* Odhner, 1914.
Sub-fam. : *HETEROPHYINÆ* Ciurea, 1924.

Genus : MACROORCHIS Goto [in Ando], 1919.

1. MACROORCHIS SPINULOSUS Goto [in Ando], 1919.
    Rat hosts.—*Mus rattus*, in nature ; *Mus norvegicus* var. *albus*, experimentally.
    Location.—Intestine.
    Locality.—Japan.
    References.—Ando, 1919 ; Dollfus, 1925, 197.

Genus : METAGONIMUS Katsurada, 1912.

1. METAGONIMUS YOKOGAWA (Katsurada, 1912).
    Synonymy.—See Faust and Nishigori, 1926, 123.
    Rat hosts.—*Mus rattus, Mus norvegicus.*
    Location.—Intestinal mucosa.
    Locality.—Japan, Central and South China, Korea, Formosa, Roumania.
    Remarks.—Infection is stated to have been obtained in rats experimentally but not in nature.
    References.—Katsurada, 1912.

Genus : CRYPTOCOTYLE Lühe, 1899.

1. CRYPTOCOTYLE CONCAVUM (Creplin, 1825).
    Rat hosts.—*Mus norvegicus.*
    References.—Creplin, 1825 ; Witenberg, 1929, 180.

Genus: T O C O T R E M A Looss, 1899.

1. TOCOTREMA LINGUA (Creplin, 1825).

Rat hosts.—Recorded as *Rattus albus.*

References.—Creplin, 1825 ; Witenberg, 1929, 181.

Sub-fam. : *CENTROCESTINÆ* Looss, 1899.

Genus: S T A M N O S O M A Tanabe, 1922.

1. STAMNOSOMA ARMATUM Tanabe, 1922.

Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*

Location.—Intestine.

Locality.—Japan.

References.—Tanabe, 1922A.

2. STAMNOSOMA FORMOSANUM Nishigori, 1924.

Synonymy.—*Centrocestus cuspidatus* var. *caninus* Leiper, 1913, is recorded as a doubtful synonym by Faust and Nishigori, 1926, 124.

Rat hosts.—White rats.

Location.—Intestine.

Locality.—Formosa.

Remarks.—Infection of white rats appears to be experimental.

References.—Nishigori, 1924A.

Genus: A s c o c o t y l e Looss, 1899.

1. ASCOCOTYLE (PHAGICOLA) ARNALDOI Travassos, 1928.

Rat hosts.—*Mus norvegicus.*

Location.—Small intestine.

Locality.—Rio de Janeiro and São Paulo, Brazil.

References.—Travassos, 1928, 2 ; 1929, 27 ; 1930, 72.

2. ASCOCOTYLE (PHAGICOLA) DIMINUTA Stunkard and Haviland, 1924.

Synonymy.—*Ascocotyle* (*Parascocotyle*) *diminuta* St. and Hav., 1924 ; *Parascocotyle minuta* Looss, 1899.

Rat hosts.—*Mus norvegicus,* infection occurring naturally.

Location.—Small intestine.

Locality.—New York, U.S.A.

Remarks.—Witenberg (*vide infra*) considers *Parascocotyle diminuta* of Stunkard and Haviland a synonym of *Parascocotyle minuta* Looss. Travassos, however, apparently considers it a valid species and quotes Witenberg's *Parascocotyle minuta* as a synonym.

References.—Stunkard and Haviland, 1924, 4 ; Dollfus, 1925 192 ; Witenberg, 1929, 187 ; Travassos, 1930, 71.

Genus : P Y G I D I O P S I S Looss, 1907.

1. PYGIDIOPSIS (?) MACROSTOMUM Travassos, 1928.
   Rat hosts.—*Mus norvegicus.*
   Location.—Small intestine.
   Locality.—Rio de Janeiro, Brazil.
   References.—Travassos, 1928, 3.

Sub-fam. : *MICROPHALLINÆ* Ward, 1901.
Genus : M I C R O P H A L L U S Ward, 1901.

1. MICROPHALLUS MINUS Ochi, 1928.
   Rat hosts.—Recorded as wild rats.
   Locality.—Japan.
   References.—Ochi, 1928, 4, this reference being taken from the *Zoological Record*, Vol. LXV, 1928, Part VI, Vermes, p. 49.

Fam. : *E C H I N O S T O M A T I D Æ* Looss, 1902.
Sub-fam. : *ECHINOSTOMATINÆ* Looss, 1899.

Genus : E C H I N O S T O M A Rudolphi, 1809.

1. ECHINOSTOMA ÆGYPTIACA Khalil and Abaza, 1924.
   Rat hosts.—*Mus rattus.*
   Location.—Small intestine.
   Locality.—Cairo, Egypt. Infection occurs naturally.
   References.—Khalil and Abaza, 1924 ; Dollfus, 1925, 185.

2. ECHINOSTOMA CINETORCHIS Ando and Ozaki, 1923.
   Rat hosts.—*Mus norvegicus.*
   Location.—Intestine.
   Locality.—Japan. Infection occurs naturally.
   References.—Ando and Ozaki, 1923, 109 ; Dollfus, 1925, 85.

3. ECHINOSTOMA GOTOI Ando and Ozaki, 1923.
   Rat hosts.—*Mus norvegicus.*
   Location.—Intestine.
   Locality.—Japan. Infection occurs naturally.
   References.—Ando and Ozaki, 1923, 112 ; Dollfus, 1925, 91.

4. ECHINOSTOMA MACRORCHIS Ando and Ozaki, 1923.
   Rat hosts.—*Mus rattus, Mus norvegicus.*
   Location.—Intestine.
   Locality.—Japan. Infection occurs naturally.
   References.—Ando and Ozaki, 1923, 115 ; Dollfus, 1925, 94.

5. ECHINOSTOMA SPICULATOR Dujardin, 1845.
   Rat hosts.—*Mus norvegicus.*
   Location.—Small intestine.
   Locality.—Rennes, France ; Germany.
   Remarks.—Infection is stated to occur naturally.
   References.—Dujardin, 1845, 424 ; Dollfus, 1925, 100.

Genus : E U P A R Y P H I U M Dietz, 1909.

1. EUPARYPHIUM GUERREROI Tubangui, 1931.
   Rat hosts.—*Mus norvegicus.*
   Location.—Small intestine.
   Locality.—Manila, Luzon, Philippine Islands.
   References.—Tubangui, 1931, 280.

2. EUPARYPHIUM ILOCANUM (Garrison, 1908) Tubangui, 1931.
   Synonyms.—*Fascioletta ilocana* Garrison, 1908 ; *Echinsotomum ilocanum* (Garrison, 1908) Odhner, 1911.
   Rat hosts.—*Mus norvegicus.*
   Location.—Small intestine.
   Locality.—Zambales, Ilocos Sur, Manila (? Ilocos Norte), Luzon.
   References.—Garrison, 1908 ; Odhner, 1911 ; Hilario and Wharton, 1917 ; Tubangui, 1931, 274.

Genus : E C H I N O P A R Y P H I U M Dietz, 1909.

1. ECHINOPHARYPHIUM JAPONICUM Ando and Ozaki, 1923.
   Rat hosts.—*Mus norvegicus.*

Location.—Intestine.

Locality.—Japan. Infection occurs naturally.

References.—Ando and Ozaki, 1923, 117 ; Dollfus, 1925, 97.

Sub-fam. : *ECHINOCHASMINÆ* Odhner, 1910.

Genus : E C H I N O C H A S M U S Dietz, 1909.

1. ECHINOCHASMUS ELONGATUS Miki, 1926.

    Rat hosts.—Recorded as " experimental infection of rat."

    Locality.—? Japan.

    References.—Miki, 1923.

Genus : H E T E R E C H I N O S T O M A Odhner, 1910.

1. HETERECHINOSTOMA MAGNIOVATUM Stunkard and Haviland, 1924.

    Rat hosts.—*Mus norvegicus.*

    Location.—Small intestine.

    Locality.—New York, U.S.A. Infection occurs naturally.

    References.—Stunkard and Haviland, 1924, 7 ; Dollfus, 1925, 101.

Fam. : *S C H I S T O S O M A T I D Æ* Looss, 1899.

Genus : S C H I S T O S O M A Weinland, 1858.

1. SCHISTOSOMA JAPONICUM Katsurada, 1904.

    Rat hosts.—Recorded as *Mus* sp. " rat des champs."

    Locality.—Japan, China, Formosa and Philippine Islands.

    Remarks.—Infection is stated to have been obtained experimentally and has also been encountered in nature in *Mus* spp.

    References.—Katsurada, 1904 ; Dollfus, 1925, 196.

Genus : S C H I S T O S O M A T I U M Tanabe, 1923.

1. SCHISTOSOMATIUM PATHLOCOPTICUM Tanabe, 1923.

    Rat hosts.—White rats.

    Location.—Liver.

    Locality.—Environs of Boston, Mass., U.S.A.

    Remarks.—The natural host for the adult is stated to be unknown ; rats and mice were infected experimentally.

    References.—Tanabe, 1923.

SYSTEMATIC POSITION UNCERTAIN.

1. DISTOMA sp. Podiapolsky, 1924.
   Rat hosts.—*Mus norvegicus.*
   Location.—Stomach.
   Locality.—Russia.
   Remarks.—The description of this species is based upon immature specimens. Dollfus (1925) considers it probable that the rat is not the normal host of this fluke.
   References.—Podiapolsky, 1924 ; Dollfus, 1925, 201.

2. DISTOMUM MIGRANS Dujardin, 1845.
   Rat hosts.—*Mus rattus, Mus norvegicus.*
   Location.—Intestine.
   Remarks.—The general opinion concerning this species is that it should be considered as doubtful.
   References.—Dujardin, 1845, 407.

3. EXORCHIS OVIFORMIS Kobayashi, 1915.
   Rat hosts.—*Mus rattus.*
   Location.—Intestine.
   Locality.—Japan.   Infection occurs naturally.
   References.—Kobayashi, 1915 ; this reference is taken from the *Zoological Record*, Vol. LII, 1915, Part VI, Vermidea, pp. 10 and 22.   Dollfus, 1925, 196.

CESTODA.

Order : C Y C L O P H Y L L I D E A Braun, 1900.

Fam. : *A N O P L O C E P H A L I D Æ* Fuhrmann, 1907.
Sub-fam. : *LINSTOWINÆ* Fuhrmann, 1907.

Genus : I N E R M I C A P S I F E R Janicki, 1910.

1. INERMICAPSIFER ARVICANTHIDIS (Kofend, 1917).
   Rats hosts.—Recorded from the rat spp. '' houmba,'' '' timmun,'' '' tschakoja,'' '' tuglidaidi.''

Location.—Intestine.

Locality.—Belgian Congo, Dahomey, French Guinea, Kordofan, Transvaal.

References.—Kofend, 1917 ; 1921. Baer, 1926, 85 ; 1927, 153. Joyeux and Mathias, 1926, 334. Meggitt and Subramanian, 1927, 196.

Genus : M U L T I C A P S I F E R I N A Fuhrmann, 1920.

1. MULTICAPSIFERINA GUINEENSIS (Graham, 1908).

Rat hosts.—*Mus rattus, Mus norvegicus*.

Location.—Intestine.

Locality.—Gold Coast, Angola, London (Zoo.), North Africa, Sierra Leone, Zanzibar.

Remarks.—Synonymy is given by Meggitt and Subramanian (1927).

References.—Graham, 1909 ; Meggitt and Subramanian, 1927, 196 ; Southwell and Maplestone, 1921.

2. MULTICAPSIFERINA MURICOLA (Baylis, 1915).

Synonym.—*Zschokkeella muricola* Baylis, 1915.

Rat hosts.—*Mus ? rattus*. Baylis (1915) states that the precise determination of the host was not given but it was probably the Black Rat which is the prevailing species in the locality.

Locality.—Accra, Gold Coast.

Remarks.—Southwell and Maplestone (1921) and Meggitt and Subramanian (1927) consider this species identical with *Multicapsiferina guineensis* (Graham, 1908).

References.—Baylis, 1915 ; Southwell and Maplestone, 1921 ; Meggitt and Subramanian, 1927, 196.

Genus : O O C H O R I S T I C A Lühe, 1899.

1. OOCHORISTICA SYMMETRICA (Baylis, 1927).

Synonym.—*Catenotænia symmetrica* Baylis, 1927.

Rat hosts.—*Mus rattus*.

Location.—Intestine.

Locality.—England.

References.—Baylis, 1927 ; Meggitt and Subramanian, 1927, 207.

Fam.: *D A V A I N E I D Æ* Fuhrmann, 1907.

Sub-fam.: *DAVAINEINÆ* Braun, 1900.

Genus: R A I L L I E T I N A Fuhrmann, 1920.

1. RAILLIETINA BÆRI Meggitt and Subramanian, 1927.

　　Synonym.—Raillietina celebensis of Southwell, and Joyeux and Baer.

　　Rat hosts.—Mus rattus.

　　*Location.—*Intestine.

　　*Locality.—*Accra, Dahomey, Tonkin.

　　*Remarks.—*According to Meggitt and Subramanian (1927) the species described by Southwell (1921) from *M. rattus* from Accra as *R. celebensis* and the form found by Joyeux and Baer (1927) in Dahomey, also stated to be *R. celebensis*, differ so markedly in scolex characters from *R. celebensis* (Janicki, 1902) from the Celebes that the Burmese cestodes are given as *R. celebensis* and the others placed in a new species, *R. baeri*. The form described by Janicki has not been recorded from rats recognised as hosts for the purposes of this paper.

　　*References.—*Meggitt and Subramanian, 1927, 198 ; Southwell, 1921 ; Joyeux and Baer, 1927, 34 ; Janicki, 1902 ; Joyeux and Houdemer, 1927, 294.

2. RAILLIETINA CELEBENSIS PAUCICAPSULATA Meggitt and Subramanian, 1927.

　　Rat hosts.—Mus norvegicus.

　　*Locality.—*Rangoon.

　　*Remarks.—*Meggitt and Subramanian (1927) state that this new variety agrees closely with *R. celebensis* (Janicki, 1902) except for the gravid proglottides which are clearly different in the two forms. This character, however, is not considered sufficiently important to justify the creation of a new species.

　　*References.—*Meggitt and Subramanian, 1927, 199.

3. RAILLIETINA FATALIS Meggitt and Subramanian, 1927.

　　Rat hosts.—Mus norvegicus.

　　*Locality.—*Rangoon

　　*References.—*Meggitt and Subramanian, 1927, 199.

4. RAILLIETINA FLUXA Meggitt and Subramanian, 1927.
    Rat hosts.—*Mus norvegicus.*
    Locality.—Rangoon.
    References.—Meggitt and Subramanian, 1927, 200.

5. RAILLIETINA FUNEBRIS Meggitt and Subramanian, 1927.
    Rat hosts.—*Mus norvegicus.*
    Locality.—Rangoon.
    References.—Meggitt and Subramanian, 1927, 200.

6. RAILLIETINA (PARONIELLA) RETRACTILIS (Stiles, 1895).
    Synonym.—*Davainea retractilis* Stiles, 1895.
    Rat hosts.—*Mus rattus.*
    Locality.—Dahomey.
    References.—Stiles, 1895, 343 ;   Joyeux and Baer, 1927, 34 ;
        Meggitt and Subramanian, 1927, 202.

7. RAILLIETINA sp. (Johnston, 1918).
    Synonym.—*Davainea* sp. Johnston, 1918.
    Rat hosts.—*Mus norvegicus.*
    Locality.—Brisbane, Australia.
    References.—Johnston, 1918, 56 ;   Meggitt and Subramanian,
        1927, 203.

        Fam. : *H Y M E N O L E P I D I D Æ* Railliet and Henry, 1909.
            Sub-fam. : *DILEPININÆ* Fuhrmann, 1907.

                Genus : C H O A N O T Æ N I A Railliet, 1896.

1. CHOANOTÆNIA sp. (Joyeux and Baer, 1927).
        Synonym.—*Icterotænia* sp. Joyeux and Baer, 1927.
        Rat hosts.—Recorded as Rat sp.
        Locality.—French Guinea.
        Remarks.—Meggitt and Subramanian (1927) consider this form,
            found by Joyeux and Baer, in which the rostellar hooks had
            been lost, to be a *Choanotænia* sp. or a *Catenotænia* sp. depending
            upon the presence or absence of a rostellum.
        References.—Joyeux and Baer, 1927, 35 ; Meggitt and Subramanian,
            1927, 206.

Sub-fam. : *HYMENOLEPIDINÆ* Ransom, 1909.

Genus : H Y M E N O L E P I S Weinland, 1858.

1. HYMENOLEPIS CONTRACTA Janicki, 1904.

Rat hosts.—*Mus norvegicus.*

Location.—Intestine.

Locality.—Germany.

References.—Janicki, 1904, 778 ; Meggitt and Subramanian, 1927, 208.

2. HYMENOLEPIS CRASSA Janicki, 1904.

Rat hosts.—*Mus norvegicus.*

Location.—Intestine.

Remarks.—Meggitt and Subramanian (1927) consider this species synonymous with *H. diminuta* (Rudolphi, 1819).

References.—Janicki, 1904, 778 ; Baylis, 1922, 7 ; Meggitt and Subramanian, 1927, 208.

3. HYMENOLEPIS DIMINUTA (Rudolphi, 1819) Blanchard, 1891.

Synonyms.—See Meggitt and Subramanian, 1927, 208.

Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*

Location.—Intestine.

Locality.—Cosmopolitan.

References.—Rudolphi, 1819, 689 ; Meggitt and Subramanian, 1927, 208.

4. HYMENOLEPIS DIMINUTOIDES Cholodkovsky, 1912.

Rat hosts.—*Mus norvegicus.*

Location.—Intestine.

Remarks.—Meggitt and Subramanian (1927) consider this species synonymous with *H. diminuta* (Rudolphi, 1819).

References.—Cholodkovsky, 1912, 50 ; Meggitt and Subramanian, 1927, 208.

5. HYMENOLEPIS GLOBIROSTRIS Baer, 1925.

Rat hosts.—Recorded as Rat " houmba " sp.

Location.—Intestine.

Locality.—Belgian Congo.

References.—Baer, 1925, 243 ; Meggitt and Subramanian, 1927, 209.

6. HYMENOLEPIS HORRIDA (Linstow, 1900).
    Rat hosts.—*Mus norvegicus.*
    Location.—Intestine.
    Locality.—Germany, Russia.
    References.—Linstow, 1900 ; Meggitt and Subramanian, 1927, 210.

7. HYMENOLEPIS INEXSPECTATA Cholodkovsky, 1912.
    Rat hosts.—*Mus norvegicus.*
    Location.—Intestine.
    Remarks.—Meggitt and Subramanian (1927) consider this species as a dubious synonym of *H. nana* (Siebold, 1852). Baylis (1922) mentions that the description of *H. inexspectata* is so very brief that it scarcely suffices to determine whether or not it is distinct from *H. longior* Baylis, 1922.
    References.—Cholodkovsky, 1912, 50 ; Baylis, 1922, 8 ; Meggitt and Subramanian, 1927, 211.

8. HYMENOLEPIS INTERMEDIUS Bacigalupo, 1927.
    Rat hosts.—Recorded as Rat sp. in nature ; white rats infected experimentally.
    Location.—Intestine.
    Locality.—Buenos Aires, Argentina.
    References.—Bacigalupo, 1927.

9. HYMENOLEPIS LONGIOR Baylis, 1922.
    Rat hosts.—*Mus rattus, Mus norvegicus.*
    Location.—Intestine.
    Remarks.—Meggitt and Subramanian (1927) consider this species synonymous with *H. nana* (Siebold, 1852).
    References.—Baylis, 1922 ; Meggitt and Subramanian, 1927, 211.

10. HYMENOLEPIS MICROSTOMA (Dujardin, 1845).
    Synonyms.—See Meggitt and Subramanian (1927).
    Rat hosts.—*Mus rattus, Mus norvegicus.*
    Location.—Intestine.
    Locality.—France, Germany, S. Oran.
    References.—Dujardin, 1845, 565 ; Joyeux and Kobozieff, 1928 ; Meggitt and Subramanian, 1927, 210.

11. HYMENOLEPIS NANA (Siebold, 1852) Blanchard, 1891.

   Synonyms.—See Meggitt and Subramanian (1927).

   Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*

   Location.—Intestine.

   Locality.—Cosmopolitan.

   Remarks.—While it is still a debated question as to whether the form known as *H. nana fraterna* Stiles, 1906 (= *Tænia murina* Dujardin, 1845) in rats and mice, generally admitted to be morphologically indistinguishable from the human form, *H. nana*, is specifically distinct or not it is considered here as synonymous with *H. nana*. Stiles (1906) maintains that the rat form should be viewed as a host sub-species. Other forms, *viz., H. fraterna* Stiles, 1906 ; *H. inexspectata* Cholodkovsky, 1912 ; *H. longior* Baylis, 1922, are all considered by Meggitt and Subramanian (1927) as synonyms of *H. nana*.

   References.—von Siebold, 1852, 64 ; Stiles, 1906, 51 ; Meggitt and Subramanian, 1927, 211.

12. HYMENOLEPIS RELICTA (Zschokke, 1887).

   Rat hosts.—*Mus norvegicus.*

   Location.—Intestine.

   Remarks.—Meggitt and Subramanian (1927) consider the differences between this form and *H. diminuta* (Rudolphi, 1819) are so slight that it should be considered as a synonym of *H. diminuta*. They also mention that Ransom thinks the two species are identical. Lühe (1910), however, recognises them as distinct species.

   References.—Zschokke, 1887, 162 ; Lühe, 1910, 87 ; Meggitt and Subramanian, 1927, 209.

   Fam.: *M E S O C E S T O I D I D Æ* Fuhrmann, 1907.
      Genus: M E S O C E S T O I D E S Vaillant, 1863.

1. MESOCESTOIDES LINEATUS (Goeze, 1782).

   Synonyms.—See Meggitt and Subramanian (1927).

   Rat hosts.—Larval stage in *Mus norvegicus.*

   Locality.—France, Germany, Iceland, Italy, Russia, Roumania, South Africa, U.S.A., Poland.

References.—Goeze, 1782, 352 ; Cameron, 1925, 43 ; Meggitt and Subramanian, 1927, 213.

Fam. : *T Æ N I I D Æ* Ludwig, 1886.
Genus : C A T E N O T Æ N I A Janicki, 1904.

1. CATENOTÆNIA LOBATA Baer, 1925.
   Rat hosts.—Recorded as Rat " tschakoja " sp.
   Location.—Intestine.
   Locality.—Dahomey, Belgian Congo, England.
   References.—Baer, 1925, 244 ; Joyeux and Baer, 1927, 35 ; Meggitt and Subramanian, 1927, 215.

2. CATENOTÆNIA PUSILLA (Goeze, 1782).
   Synonyms.—See Meggitt and Subramanian (1927).
   Rat hosts.—*Mus rattus, Mus norvegicus.*
   Location.—Intestine.
   Locality.—England, France, Germany, Ireland, U.S.A.
   References.—Goeze, 1782, 335 ; Meggitt and Subramanian, 1927, 215.

Genus : M U L T I C E P S Goeze, 1782.

1. MULTICEPS SERIALIS (Gervais, 1847) Stiles and Stevenson, 1905.
   Synonyms.—See Meggitt and Subramanian (1927).
   Rat hosts.—*Mus norvegicus.*
   Location.—Larval stage in liver.
   Locality.   Cosmopolitan.
   Remarks.—Meggitt and Subramanian consider that the *Cœnurus* sp. recorded by Turner in 1919 is synonymous with this form.
   References.—Gervais, 1847, 98 ; Turner, 1919 ; Meggitt and Subramanian, 1927, 217.

Genus : T Æ N I A Linnaeus, 1758.

1. TÆNIA BRACHYDERA Diesing, 1854.
   Rat hosts.—*Mus norvegicus.*
   Location.—Intestine.
   Locality.—Ireland.
   Remarks.—Lühe (1910) and Janicki (1906) consider this form as possibly identical with *Hymenolepis microstoma* (Dujardin 1845) ; Meggitt and Subramanian (1927) list it as a synonym.

References.—Diesing, 1854, 607 ; Lühe, 1910, 86 ; Janicki, 1906 ; Meggitt and Subramanian, 1927, 210.

2. TÆNIA CRASSICEPS (Zeder, 1800).

Synonyms.—See Meggitt and Subramanian (1927).

Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus.*

Location.—Larval stage in liver and sub-cutaneous tissue.

Locality.—France, Germany, Roumania, Switzerland.

References.—Zeder, 1800, 233 ; Meggitt and Subramanian, 1927, 217.

3. TÆNIA HYDATIGENA (Pallas, 1766).

Synonyms.—See Meggitt, 1924, 87.

Rat hosts.—*Mus rattus, Mus norvegicus.*

Location.—Larval stage in liver and mesentery of abdominal cavity. (*Cysticercus tenuicollis* Rudolphi, 1810).

Locality.—Cosmopolitan.

References.—Pallas, 1766, 157 ; Hall, 1919, 29 ; Meggitt and Subramanian, 1927, 218.

4. TÆNIA MURIS-RATTI (Creplin, 1825).

Rat hosts.—*Mus rattus.*

Location.—Intestine.

Remarks.—Meggitt and Subramanian (1927) consider this as an invalid species.

References.—Creplin, 1825, 73 ; Meggitt and Subramanian, 1927, 223.

5. TÆNIA PISIFORMIS (Bloch, 1780).

Synonyms.—See Meggitt, 1924, 91.

Rat hosts.—*Mus rattus.*

Location.—Larval stage, *Cysticercus pisiformis*, in liver.

Locality.—Cosmopolitan.

References.—Bloch, 1780, 338 ; Hall, 1919, 25 ; Meggitt and Subramanian, 1927, 218.

6. TÆNIA RATTI Rudolphi, 1819.

Rat hosts.—*Mus rattus.*

Location.—Intestine.

Remarks.—Considered by Janicki (1906) as a dubious species ; by Diesing as identical with *Hymenolepis diminuta* ; and by

Meggitt and Subramanian (1927) as an invalid species.

References.—Rudolphi, 1819, 170 ;   Janicki, 1906, 581 ;   Meggitt
and Subramanian, 1927, 224.

7. TÆNIA SOLIUM Linnaeus, 1758.

Synonyms.—See Meggitt, 1924, 93.

Rat hosts.—*Mus rattus* and *Mus* spp.

Location.—Larval stage, *Cysticercus cellulosæ* (Gmelin, 1790),
in musculature and peritoneum.

Locality.—Cosmopolitan.

References.—Linnaeus, 1758, 819 ;   Meggitt and Subramanian,
1927, 219.

8. TÆNIA TÆNIÆFORMIS (Batsch, 1786).

Synonyms.—See Meggitt, 1924, 94.

Rat hosts.—*Mus rattus*, *Mus norvegicus*, *Mus rattus* var. *alex-
andrinus*.

Location.—Larval stage, *Cysticercus fasciolaris* Rudolphi, 1808,
in liver.

Locality.—Cosmopolitan.

Remarks.—Meggitt and Subramanian (1927) discuss the various
views regarding the nomenclature of this form pointing out
that the proposal of Sambon to change the generic name to
Reditænia or to *Hydatigera*, subsequently proposed, has not
met with general acceptance, some authors refusing recognition.
Sambon's proposal is based upon larval characters and it is
pointed out that it is debatable as to whether such characters
constitute generic differences or not.   The generally accepted
generic name is here retained.

References.—Batsch, 1786, 100 ;   Meggitt and Subramanian, 1927,
219.

9. TÆNIA UMBONATA Molin, 1858.

Rat hosts.—*Mus rattus.*

Location.—Intestine.

Remarks.—Meggitt and Subramanian (1927) consider this form
as an invalid species noting that Blanchard holds the view
that it may be possibly identical with *Catenotænia pusilla*
(Goeze, 1782) and that Janicki considers it a dubious species.

References.—Molin, 1858, 138 ; Meggitt and Subramanian, 1927, 224.

Order :   P S E U D O P H Y L L I D E A Carus, 1863.
Fam. : *D I P H Y L L O B O T H R I I D Æ* Lühe, 1910.
Sub-fam. : *D I P H Y L L O B O T H R I I N Æ* Lühe, 1910.

Genus : D I P H Y L L O B O T H R I U M Cobbold, 1858.

1. DIPHYLLOBOTHRIUM MANSONI (Cobbold, 1883).
   Synonyms.—See Meggitt and Subramanian (1927).
   Rat hosts.—*Mus rattus*, *Mus rattus* var. *alexandrinus*, *Mus norvegicus*, '' Japanese rat.''
   Location.—Larval stage, *Sparganum mansoni* Cobbold, 1883, in somatic muscles, sometimes in iliac fossæ, pleural cavity and lumbar region.
   Locality.—China, Japan, Tonkin, Porto Rico.
   Remarks.—Meggitt and Subramanian (1927) consider that in all probability *Bothriocephalus ratticola* Linstow, 1904, from the Alexandrine rat in Singapore is synonymous with this form as the characters given are not sufficient to distinguish it.
   References.—Cobbold, 1883 ; Joyeux and Houdemer, 1928, 30 ; Meggitt and Subramanian, 1927, 222.

Fam. : *P T Y C H O B O T H R I I D Æ* Lühe, 1902.

Genus : B O T H R I O C E P H A L U S Rudolphi, 1808.

1. BOTHRIOCEPHALUS RATTICOLA Linstow, 1904.
   Rat hosts.—*Mus rattus* var. *alexandrinus*.
   Location.—Larval stage in liver.
   Locality.—Singapore.
   Remarks.—This form is considered by Meggitt and Subramanian (1927) as synonymous with *Diphyllobothrium mansoni* (Cobbold, 1883).
   References.—v. Linstow, 1904, 682 ; Shipley, 1908, 78 ; Meggitt and Subramanian, 1927, 222.

LARVAL FORMS.

Genus: D I T H Y R I D I U M Rudolphi, 1819.

1. DITHYRIDIUM ELONGATUM (Blumberg, 1882).

Synonyms.—See Meggitt and Subramanian (1927).

Rat hosts.—Mus norvegicus.

Location.—Pleural or peritoneal cavity.

Locality.—Austria, France, Germany, Poland, Russia, U.S.A.

References.—Blumberg, 1882 ; Meggitt and Subramanian, 1927, 214.

2. DITHYRIDIUM spp. Skrjabin and Schulz, 1926.

Rat hosts.—Mus norvegicus.

Location.—Abdominal cavity.

Locality.—Russia.

Remarks.—The authors state that on the basis of agreement in size and shape of the scoleces this form is considered to be the larval stage of Mesocestoides lineatus (Goeze, 1782). Meggitt and Subramanian, while admitting the plausibility of the hypothesis, prefer to await further confirmation.

References.—Skrjabin and Schulz, 1926 ; Meggitt and Subramanian, 1927, 214.

NEMATODA.

Order : A S C A R O I D E A Railliet and Henry, 1915.

Fam : H E T E R A K I D Æ Railliet and Henry, 1914.
Sub-fam. : HETERAKINÆ Railliet and Henry, 1912.

Genus : H E T E R A K I S Dujardin, 1845.

1. HETERAKIS (GANGULETERAKIS) SPUMOSA (Schneider, 1866).

Rat hosts.—Mus rattus, Mus rattus var. alexandrinus, Mus norvegicus.

Location.—Large intestine and cæcum.

Locality.—Australia, U.S.A., etc. ; Cosmopolitan.

References.—Schneider, 1866, 77 ; Johnston, 1918 ; Moll, 1917, 90 ; Hall, 1916, 45.

Fam.: *O X Y U R I D Æ* Cobbold, 1864.

Sub-fam.: *OXYURINÆ* Hall, 1916.

Genus: S Y P H A C I A Seurat, 1916.

1. SYPHACIA OBVELATA (Rudolphi, 1802).

    Synonyms.—? *Oxyuris stroma* Linstow, 1884. See Hall (1916).

    Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*

    Location.—Cæcum and large intestine.

    Locality.—England, Australia, etc.; Cosmopolitan.

    References.—Rudolphi, 1802, 18; Johnston, 1918; Balfour, 1922, 290; Hall, 1916, 81.

Fam.: *R H A B D I T I D Æ* Micoletzky, 1922.

Sub-fam.: *RHABDITINÆ* Micoletzky, 1922.

Genus: S T R O N G Y L O I D E S Grassi, 1879.

1. STRONGYLOIDES PAPILLOSUS (Wedl, 1856) Ransom, 1911.

    Synonyms.—See Hall, 1916, 7.

    Rat hosts.—*Mus norvegicus.*

    Location.—Intestine.

    Locality.—Europe, U.S.A., ? South America.

    References.—Wedl, 1856, 129; Hall, 1916, 7.

2. STRONGYLOIDES RATTI Sandground, 1925.

    Rat hosts.—*Mus norvegicus.*

    Location.—Intestine.

    Locality.—Baltimore, U.S.A.

    References.—Sandground, 1925, 73.

3. STRONGYLOIDES sp. Parona, 1894.

    Rat hosts.—*Mus norvegicus.*

    References.—Parona, 1894, 248.

Order: S T R O N G Y L O I D E A Weinland, 1858.

Fam.: *T R I C H O S T R O N G Y L I D Æ* Leiper, 1912.

Sub-fam.: *HELIGMOSOMINÆ* Travassos, 1914.

Genus : H E L I G M O S O M U M Railliet and Henry, 1909.

1. HELIGMOSOMUM (LONGISTRIATA) ACULEATA Travassos, 1918.

  Rat hosts.—Recorded as " rato selvajem " or wild rat.
  Location.—Small intestine.
  Locality.—Brazil.
  References.—Travassos, 1918, 197 ; 1921, 91. Travassos and
  Darriba, 1929, 7.

2. HELIGMOSOMUM (LONGISTRIATA) BETA Travassos, 1918.
  Rat hosts.—Recorded as " rato selvajem " or wild rat.
  Location.—Small intestine.

  Locality.—Brazil.
  References.—Travassos, 1918, 200 ; 1921, 93. Travassos and
  Darriba, 1929, 7.

3. HELIGMOSOMUM (LONGISTRIATA) NEMATODIRIFORMIS Travassos, 1918.
  Rat hosts.—Recorded as " rato paca."
  Location.—Small intestine.
  Locality.—Brazil.
  References.—Travassos, 1918, 198 ; 1921, 92. Travassos and
  Darriba, 1929, 7.

4. HELIGMOSOMUM (LONGISTRIATA) VEXILLATUM Hall, 1916.
  Rat hosts.—*Mus norvegicus*.
  Location.—Small intestine.
  Locality.—England, Colorado.
  References.—Hall, 1916, 155 ; Balfour, 1922, 290.

Genus : N I P P O S T R O N G Y L U S Lane, 1923.

1. NIPPOSTRONGYLUS BRAZILIENSE (Travassos, 1914).
  Rat hosts.—*Mus rattus, Mus norvegicus*.
  Location.—Small intestine.
  Locality.—Brazil, Australia.
  Remarks.—Balfour (1922) records the finding of specimens of
  a " Viannaia sp. incert." in 0·7 per cent. of *Mus norvegicus*
  examined in England and considers that they may possibly
  be immature or undescribed forms of this nematode.
  References.—Travassos, 1914A, 326 ; Balfour, 1922, 290 ; Tra-
  vassos and Darriba, 1929, 7 ; Johnston, 1918.

2. NIPPOSTRONGYLUS MURIS (Yokogawa, 1920).

  Rat hosts.—*Mus norvegicus.*

  Location.—Intestine.

  Locality.—Baltimore, U.S.A.

  Remarks.—Travassos (1929) considers this species identical with *N. braziliense* (Travassos, 1914) and Travassos and Darriba (1929) cite it as a synonym.

  References.—Yokogawa, 1920 ; Travassos, 1929, 5 ; Travassos and Darriba, 1929, 7.

Order : F I L A R I O I D E A Weinland, 1858.

Fam. : *F I L A R I I DÆ* Claus, 1885.
Sub-fam. : *FILARIINÆ* Stiles, 1907.

Genus : F I L A R I A Müller, 1787.

1. FILARIA sp. Davaine, 1860.

  Rat hosts.—*Mus rattus.*

  Location.—Blood.

  Locality.—France.

  Remarks.—Hall (1916) mentions that von Linstow erroneously gives *Mus decumanus* as the host and also states that there is another record of the finding of " filiform animalcules " by Chaussat, in 1850, in the blood of *Mus rattus.* In Hall's opinion it seems likely that these forms are the common *Trypanosoma lewisi.*

  References.—Davaine, 1860 ; Hall, 1916, 190.

Genus : L I T O M O S O I D E S Chandler, 1931.

1. LITOMOSOIDES SIGMODONTIS Chandler, 1931.

  Rat hosts.—White rat.

  Location.—Thoracic cavity.

  Locality.—Houston, Texas.

  Remarks.—This form, occurring in a high percentage of cotton rats (*Sigmodon hispidus*), was also found in a white rat born and raised in the Rice Institute Animal house where some infected cotton rats were kept.

  References.—Chandler, 1931, 5.

Genus : D I R O F I L A R I A Railliet and Henry, 1911.

1. DIROFILARIA BONNEI Vogel and Vogelsang, 1930.

   Rat hosts.—*Mus rattus*.

   Location.—Peritoneum and blood.

   Locality.—Java.

   References.—Vogel and Vogelsang, 1930, 483.

Fam. : *S P I R U R I D Æ* Örley, 1885.

Sub-fam. : *SPIRURINÆ* Railliet, 1915.

Genus : S P I R U R A E. Blanchard, 1849, *nec* Diesing, 1861.

1. SPIRURA RYTIPLEURITES (Deslongchamps, 1824).

   Synonyms.—*Filaria gastrophila* Mueller, 1894.

   Rat hosts.—*Mus norvegicus* in nature ; *Mus rattus* experimentally according to Shipley (1908).

   Location.—Stomach.

   Remarks.—Hall, 1916, 202, states that Seurat considers this form, adult in the rat and with larval stages in *Blatta orientalis* and *Periplaneta americana*, is identical with *Spirura talpæ* (Gmelin, 1790). The larval stage is believed to be *Mermis blattæ-orientalis* of Diesing.

   References.—Deslongchamps, 1824, 396 ; Hall, 1916, 202.

2. SPIRURA TALPÆ (Gmelin, 1790) Blanchard, 1849.

   Synonyms.—See Hall, 1916, 199.

   Rat hosts.—Reported from Epimys sp. " rat."

   Location.—Stomach.

   Locality.—France, Germany, Austria, Ireland, Italy, Brazil.

   Remarks.—This form is usually encountered in the mole (*Talpa europæa*) in the stomach and often in the intestine.

   References.—Gmelin, 1790, 3032 ; Hall, 1916, 199.

Genus : P R O T O S P I R U R A Seurat, 1914.

1. PROTOSPIRURA BONNEI Ortlepp, 1924.

   Rat hosts.—Rat, species not recorded.

   Location.—Stomach.

   Locality.—Dutch Guiana.

   References.—Ortlepp, 1924, 23.

2. PROTOSPIRURA COLUMBIANA Cram, 1926.
    Rat hosts.—*Mus norvegicus.*
    Location.—Stomach, occasionally œsophagus and anterior end of small intestine.
    Locality.—Washington, U.S.A.
    References.—Cram, 1926.

3. PROTOSPIRURA MURICOLA Gedoelst, 1916.
    Rat hosts.—Reported from " rat indéterminé."
    Locality.—Belgian Congo.
    References.—Gedoelst, 1916, 57.

4. PROTOSPIRURA MURIS (Gmelin, 1790) Seurat, 1915.
    Synonyms.—See Hall, 1916, 204.
    Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*
    Location.—Stomach.
    Locality.—Cosmopolitan.
    References.—Gmelin, 1790, 3032 ; Schneider, 1866, 97 ; Rudolphi, 1819, 249 ; von Linstow, 1897, 30 ; Shipley, 1908, 76 ; Hall, 1916, 204.

        Sub-fam. : ARDUENNINÆ Railliet and Henry, 1911.

        Genus : G O N G Y L O N E M A Molin, 1857.

1. GONGYLONEMA MINIMUM Molin, 1857.
    Synonyms.—*Filaria musculi* Rudolphi, 1819.
    Rat hosts.—*Mus norvegicus.*
    Location.—Liver and on external walls of stomach.
    Locality.—Austria.
    References.—Molin, 1857, 217 ; Hall, 1916, 191.

2. GONGYLONEMA NEOPLASTICUM (Fibiger and Ditlevsen, 1914) Ransom and Hall, 1916.
    Synonyms.—See Hall, 1916, 193.
    Rat hosts.—*Mus rattus, Mus norvegicus, Mus norvegicus* var. *albus.*
    Location.—Œsophagus.
    Locality.—Denmark, Danish West Indies, Algeria, Argentina.
    References.—Fibiger and Ditlevsen, 1914 ; Hall, 1916, 193.

3. GONGYLONEMA ORIENTALE Yokogawa, 1925.

    Rat hosts.—White rat. Also reported as parasitic in rats and other rodents.

    Location.—Œsophagus, anterior half of stomach, tongue and mouth. Infection in white rat produced experimentally.

    Locality.—Japan.

    References.—Yokogawa, 1925.

Sub-fam.: PHYSALOPTERINÆ Stossich, 1898.

Genus: PHYSALOPTERA Rudolphi, 1819.

1. PHYSALOPTERA CIRCULARIS Linstow, 1897.

    Rat hosts.—*Mus rattus.*

    Location.—Stomach.

    Locality.—Madagascar.

    References.—von Linstow, 1897, 28; Hall, 1916, 215.

2. PHYSALOPTERA GETULA Seurat, 1917.

    Rat hosts.—*Mus rattus.*

    Locality.—Algeria.

    Reference.—Seurat, 1917, 215.

Sub-fam.: THELAZIINÆ Baylis and Daubney, 1926.

Genus: RICTULARIA Frölich, 1802.

1. RICTULARIA TANI Hoeppli, 1929.

    Rat hosts.—*Mus norvegicus.*

    Location.—Intestine.

    Locality.—Amoy, China.

    References.—Hoeppli, 1929.

Fam.: GNATHOSTOMIDÆ Railliet, 1895.

Sub-fam.: GNATHOSTOMINÆ Baylis and Lane, 1920.

Genus: GNATHOSTOMA Owen, 1836.

1. GNATHOSTOMA SPINIGERUM Owen, 1836.

    Synonyms.—See Yorke and Maplestone, 1926, 340.

    Rat hosts.—Reported from *Rattus* sp.

    Location.—Stomach.

    References.—Owen, 1836; Yorke and Maplestone, 1926, 340.

Order : T R I C H I N E L L O I D E A Hall, 1916.

Fam. : *T R I C H I N E L L I D Æ* Stiles and Crane, 1910.

Sub-fam. : *TRICHINELLINÆ* Ransom, 1911.

Genus : T R I C H I N E L L A Railliet, 1895.

1. TRICHINELLA SPIRALIS (Owen, 1835) Railliet, 1895.
    Synonyms.—See Hall, 1916, 10.
    Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*
    Location.—Adults in intestine ; larvæ encysted in muscles.
    Locality.—Cosmopolitan.
    References.—Owen, 1835 ; Shipley, 1908 ; Hall, 1916, 10.

Sub-fam. : *TRICHURINÆ* Ransom, 1911.

Genus : T R I C H U R I S Roederer, 1761.

1. TRICHURIS MURIS (Schrank, 1788) Hall, 1916.
    Synonyms.—See Hall, 1916, 26.
    Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*
    Location.—Cæcum, sometimes in intestine.
    Locality.—France, Germany, Africa, Australia.
    References.—Schrank, 1788, 4 ; Dujardin, 1845, 35 ; Shipley, 1908, 76 ; Hall, 1916, 26.

Genus : C A P I L L A R I A Zeder, 1800.

1. CAPILLARIA ANNULOSA (Dujardin, 1845) Hall, 1916.
    Synonyms.—See Hall, 1916, 35.
    Rat hosts.—*Mus rattus, Mus norvegicus.*
    Location.—Small intestine.
    Locality.—France, Ireland.
    References.—Dujardin, 1845, 27 ; Eberth, 1863, 57 ; Hall, 1916, 35.

2. CAPILLARIA (THOMINX) BACILLATA (Eberth, 1863) Hall, 1916.
    Synonyms.—*Trichosoma bacillatum* Eberth, 1863.
    Rat hosts.—*Mus norvegicus.*

Location.—Not given for rat ; this form has been reported for the mouse where it was recorded from the œsophagus. Hall (1916) states that this position is quite unusual.

References.—Eberth, 1863, 48 ; Travassos, 1915, 155 ; Hall, 1916, 34.

3. CAPILLARIA LEIDYI (Travassos, 1914).

Synonyms.—*Trichosomum tenuissimum* Leidy, 1891, *nec* Rudolphi, 1803, *nec* Diesing, 1851.

Rat hosts.—*Mus norvegicus.*

References.—Travassos, 1914B.

4. CAPILLARIA PAPILLOSA (Polonio, 1860) Hall, 1916.

Synonyms.—*Calodium papillosum* Polonio, 1860.

Rat hosts.—*Mus rattus, Mus norvegicus.*

Location.—Urinary bladder.

Locality.—Italy.

References.—Polonio, 1860, 23 ; Hall, 1916, 37.

5. CAPILLARIA SCHMIDTII (Linstow, 1874) Hall, 1916.

Rat hosts.—*Mus norvegicus.*

Location.—Urinary bladder.

Locality.—Germany.

Remarks.—Hall (1916) mentions that there is the possibility of this form being either *C. annulosa* or *C. papillosa.*

References.—von Linstow, 1874, 283 ; Hall, 1916, 37.

Genus : H E P A T I C O L A Hall, 1916.

1. HEPATICOLA GASTRICA Baylis, 1926.

Rat hosts.—*Mus rattus, Mus norvegicus.*

Location.—Stomach.

Locality.—Italy, Holland, Denmark.

References.—Baylis, 1926.

2. HEPATICOLA HEPATICA (Bancroft, 1893) Hall, 1916.

Synonyms.—See Hall, 1916, 31.

Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*

Location.—Liver.

Locality.—France, Italy, Australia, England, U.S.A., Japan, China, India.

References.—Bancroft, 1893 ; Hall, 1916, 31 ; Johnston, 1918.

3. HEPATICOLA MURIS Uyeyama, 1928.
   Rat hosts.—Recorded as '' rat blanc.''
   Location.—Stomach.
   Locality.—Japan.
   References.—Uyeyama, 1928.

Hepaticola soricicola Yokogawa, 1924. By some misadventure this species has been noted in the *Vermes* section of *The Zoological Record*, Vol. LXIII, 1926, p. 55, as occurring in the liver of rat and mouse. Reference to the original description in Nishigori's paper, '' On a New Species of the Genus Hepaticola,'' *Taiwan Ig. Kw. Z.*, 1924, No. 236 (Abstract in *Jap. J. Zool., Tokyo,* I, 1926, pp. 124-5) discloses the fact that this form is parasitic only in the common '' Musk-rat '' of Formosa, *Sorex* sp. (specific name unknown) and that '' it has not been found in the wild rat, nor the white rat or mouse even after experimental feeding.'' Although described by Nishigori, the name of the nematode is noted as having been proposed by Dr. Yokogawa. It seemed incumbent upon the writer to draw attention here to this error in host record.

Sub-fam. : *TRICHOSOMOIDINÆ* Hall, 1916.

Genus : T R I C H O S O M O I D E S Railliet, 1895.

1. TRICHOSOMOIDES CRASSICAUDA (Bellingham, 1840) Railliet, 1895.
   Synonyms.—See Hall, 1916, 13.
   Rat hosts.—*Mus rattus, Mus rattus* var. *alexandrinus, Mus norvegicus.*
   Location.—Urinary bladder, kidneys and ureters.
   Locality.—Ireland, England, Germany, Denmark, Austria, France, Australia, U.S.A.
   References.—Bellingham, 1840 ; Thomas, 1924 ; Hall, 1916, 13.

SYSTEMATIC POSITION UNCERTAIN.

Genus : S P I R O P T E R A Rudolphi, 1819.

1. SPIROPTERA RATTI Diesing, 1851.
   Rat hosts.—*Mus rattus.*
   Location.—Urinary bladder.

Locality.—Berlin, Germany.

Remarks.—According to Hall (1916) this species was proposed for a nematode recorded by Gurlt with no other data than host, location and locality, and must be regarded as a *nomen nudum.* He also states that the worm, may or may not have been *Trichosomoides crassicauda* (Bellingham, 1840).

References.—Diesing, 1851, 225 ; Hall, 1916, 221.

2. SPIROPTERA sp. Gerstaecker, 1866.

    Synonyms.—See Hall, 1916, 223.

    Rat hosts.—Recorded from *Epimys* sp., " rat " and *Mus norvegicus.*

    Location.—Encysted in walls of digestive tract.

    Locality.—Hungary Budapest . Australia (Sydney).

    Remarks.—Shipley 1908 writes concerning a form named as *Spiroptera* sp. Bakody, mentioning it to be from *Mus rattus* and *Mus norvegicus*, encapsuled in the walls of the alimentary canal and in certain muscles. Hall gives this name as a synonym of *Spiroptera* sp. of Gerstaecker. Cleland (1918) mentions that he sent larval forms of a nematode from *Mus norvegicus* to Hall who thought they were possibly earlier stages of the species named above, found by Gerstaecker.

    References.—Gerstaecker, 1866 ; Shipley, 1908 ; Hall, 1916, 223 ; Cleland, 1918, 121.

ACANTHOCEPHALA.

Order : E C H I N O R H Y N C H A T A Faust, 1930.

    Fam. : *M O N I L I F O R M I D Æ* Van Cleave, 1924.

Genus : M O N I L I F O R M I S Travassos, 1915.

1. MONILIFORMIS MONILIFORMIS Bremser, 1811) Travassos, 1915.

    Synonyms.—Complete synonymy given by Travassos, 1917, 14.

    Rat hosts.—*Mus rattus*, *Mus rattus* var. *alexandrinus*, *Mus norvegicus.*

    Location.—Intestine.

    Locality.—Australia, England, West Africa, South America, British Honduras, Porto Rico.

    References.—Bremser, 1811, 26 : Travassos, 1917 ; Rudolphi, 1819, 71.

LIST OF PARASITES.

The following list is inserted to serve as a quick means of ascertaining the known occurrence of a particular parasite in the different rat groups. The helminths are listed alphabetically in their respective Classes. The columns 1 to 4 indicate the different rat groups as follows : Col. 1, *Mus* (*Rattus*) *rattus* ; Col. 2, *Mus* (*Rattus*) *rattus* var. *alexandrinus* ; Col. 3, *Mus* (*Rattus*) *norvegicus* ; Col. 4, " Rats," specific identity not stated, including such forms as " wild rats," " rats," *Mus* sp. in conjunction with " rat," " rat sp." with native names following, *Rattus* sp., etc. A * placed in one or other of the columns indicates the occurrence of the parasite, opposite the *, in the appropriate rat group.

TREMATODA.

		(1)	(2)	(3)	(4)
1.	*Ascocotyle* (*Phagicola*) *arnaldoi* Travassos, 1928 ...			*	
2.	*Ascocotyle* (*Phagicola*) *diminuta* Stunkard and Haviland, 1924			*	
3.	*Clonorchis sinensis* (Cobbold, 1875) Looss, 1907 ...	*		*	
4.	*Cryptocotyle concavum* (Creplin, 1825)			*	
5.	*Distoma* sp. Podiapolsky, 1924			*	
6.	*Distomum migrans* Dujardin, 1845	*		*	
7.	*Echinochasmus elongatus* Miki, 1926				*
8.	*Echinoparyphium japonicum* Ando and Ozaki, 1923 ...			*	
9.	*Echinostoma ægyptiaca* Khalil and Abaza, 1924 ...	*			
10.	*Echinostoma cinetorchis* Ando and Ozaki, 1923 ...			*	
11.	*Echinostoma gotoi* Ando and Ozaki, 1923			*	
12.	*Echinostoma macrorchis* Ando and Ozaki, 1923 ...	*		*	
13.	*Echinostoma spiculator* Dujardin, 1845			*	
14.	*Euparyphium guerreroi* Tubangui, 1931			*	
15.	*Euparyphium ilocanum* (Garrison, 1908) Tubangui, 1931			*	
16.	*Exorchis oviformis* Kobayashi, 1915	*			
17.	*Heterechinostoma magniovatum* Stunkard and Haviland, 1924			*	
18.	*Lepoderma muris* Tanabe, 1922	*		*	*
19.	*Macroorchis spinulosus* Goto in Ando, 1919	*			*
20.	*Metagonimus yokogawai* (Katsurada, 1912)	*		*	
21.	*Microphallus minus* Ochi, 1928				*
22.	*Pygidiopsis* (?) *macrostomum* Travassos, 1928 ...			*	
23.	*Schistosoma japonicum* Katsurada, 1904				*
24.	*Schistosomatium pathlocopticum* Tanabe, 1923 ...				*
25.	*Stamnosoma armatum* Tanabe, 1922	*	*	*	
26.	*Stamnosoma formosanum* Nishigori, 1924			*	
27.	*Tocotrema lingua* (Creplin, 1825)			*	

CESTODA.

		(1)	(2)	(3)	(4)
28.	*Bothriocephalus ratticola* Linstow, 1904	*			
29.	*Catenotænia lobata* Baer, 1925				*
30.	*Catenotænia pusilla* (Goeze, 1782)	*		*	
31.	*Choanotænia* sp. (Joyeux and Baer, 1927)				*
32.	*Diphyllobothrium mansoni* (Cobbold, 1883)	*	*	*	*
33.	*Dithyridium elongatum* (Blumberg, 1882)			*	
34.	*Dithyridium* sp. Skrjabin and Schulz, 1926			*	
35.	*Hymenolepis contracta* Janicki, 1904			*	
36.	*Hymenolepis crassa* Janicki, 1904			*	
37.	*Hymenolepis diminuta* (Rudolphi, 1819) Blanchard, 1891	*	*	*	
38.	*Hymenolepis diminutoides* Cholodkovsky, 1912			*	
39.	*Hymenolepis globirostris* Baer, 1925				*
40.	*Hymenolepis horrida* (Linstow, 1900)			*	
41.	*Hymenolepis inexspectata* Cholodkovsky, 1912			*	
42.	*Hymenolepis intermedius* Bacigalupo, 1927				*
43.	*Hymenolepis longior* Baylis, 1922	*		*	
44.	*Hymenolepis microstoma* (Dujardin, 1845)	*		*	
45.	*Hymenolepis nana* (Siebold, 1852) Blanchard, 1891	*	*	*	
46.	*Hymenolepis relicta* (Zschokke, 1887)			*	
47.	*Inermicapsifer arvicanthidis* (Kofend, 1917)				*
48.	*Mesocestoides lineatus* (Goeze, 1782)			*	
49.	*Multicapsiferina guineensis* (Graham, 1908)	*		*	
50.	*Multicapsiferina muricola* (Baylis, 1915)	*			
51.	*Multiceps serialis* (Gervais, 1847) Stiles and Stevenson, 1905			*	
52.	*Oochoristica symmetrica* (Baylis, 1927)	*			
53.	*Raillietina baeri* Meggitt and Subramanian, 1927	*			
54.	*Raillietina celebensis paucicapsulata* Meggitt and Subramanian, 1927			*	
55.	*Raillietina fatalis* Meggitt and Subramanian, 1927			*	
56.	*Raillietina fluxa* Meggitt and Subramanian, 1927			*	
57.	*Raillietina funebris* Meggitt and Subramanian, 1927			*	
58.	*Raillietina* (*Paroniella*) *retractilis* (Stiles, 1895)	*			
59.	*Raillietina* sp. (Johnston, 1918)			*	
60.	*Tænia brachydera* Diesing, 1854			*	
61.	*Tænia crassiceps* (Zeder, 1800)	*	*		
62.	*Tænia hydatigena* (Pallas, 1766)	*	*		
63.	*Tænia muris-ratti* (Creplin, 1825)	*			
64.	*Tænia pisiformis* (Bloch, 1780)	*			
65.	*Tænia ratti* Rudolphi, 1819	*			
66.	*Tænia solium* Linnaeus, 1758	*			*
67.	*Tænia tæniæformis* (Batsch, 1786)	*	*	*	
68.	*Tænia umbonata* Molin, 1858	*			

NEMATODA.

		(1)	(2)	(3)	(4)
69.	*Capillaria annulosa* (Dujardin, 1845) Hall, 1916 ...	*		*	
70.	*Capillaria (Thominx) bacillata* (Eberth, 1863) Hall, 1916...			*	
71.	*Capillaria leidyi* (Travassos, 1914)			*	
72.	*Capillaria papillosa* (Polonio, 1860) Hall, 1916 ...	*		*	
73.	*Capillaria schmidtii* (Linstow, 1874) Hall, 1916 ...			*	
74.	*Dirofilaria bonnei* Vogel and Vogelsang, 1930 ...	*			
75.	*Filaria* sp. Davaine, 1860	*			
76.	*Gnathostoma spinigerum* Owen, 1836				*
77.	*Gongylonema minimum* Molin, 1857			*	
78.	*Gongylonema neoplasticum* (Fibiger and Ditlevsen, 1914) Ransom and Hall, 1916	*		*	*
79.	*Gongylonema orientale* Yokogawa, 1925				*
80.	*Heligmosomum (Longistriata) aculeata* Travassos, 1918				*
81.	*Heligmosomum (Longistriata) beta* Travassos, 1918...				*
82.	*Heligmosomum (Longistriata) nematodiriformis* Travassos, 1918				*
83.	*Heligmosomum (Longistriata) vexillatum* Hall, 1916			*	
84.	*Hepaticola gastrica* Baylis, 1926	*		*	
85.	*Hepaticola hepatica* (Bancroft, 1893) Hall, 1916 ...	*	*	*	
86.	*Hepaticola muris* Uyeyama, 1928				*
87.	*Heterakis (Ganguleterakis) spumosa* (Schneider, 1866)	*	*	*	
88.	*Litomosoides sigmodontis* Chandler, 1931				*
89.	*Nippostrongylus braziliense* (Travassos, 1914) ...	*		*	
90.	*Nippostrongylus muris* (Yokogawa, 1920)			*	
91.	*Physaloptera circularis* Linstow, 1897	*			
92.	*Physaloptera getula* Seurat, 1917	*			
93.	*Protospirura bonnei* Ortlepp, 1924				*
94.	*Protospirura columbina* Cram, 1926			*	
95.	*Protospirura muricola* Gedoelst, 1916				*
96.	*Protospirura muris* (Gmelin, 1790) Seurat, 1915 ...	*	*	*	
97.	*Rictularia tani* Hoeppli, 1929			*	
98.	*Spiroptera ratti* Diesing, 1851	*			
99.	*Spiroptera* sp. Gerstaecker, 1866			*	*
100.	*Spirura rytipleurites* (Deslongchamps, 1824) ...	*		*	
101.	*Spirura talpæ* (Gmelin, 1790) Blanchard, 1849 ...				*
102.	*Strongyloides papillosus* (Wedl, 1856) Ransom, 1911			*	
103.	*Strongyloides ratti* Sandground, 1925			*	
104.	*Strongyloides* sp. Parona, 1894			*	
105.	*Syphacia obvelata* (Rudolphi, 1802)	*	*	*	
106.	*Trichinella spiralis* (Owen, 1835) Railliet, 1895 ...	*	*	*	
107.	*Trichosomoides crassicauda* (Bellingham, 1840) Railliet, 1895	*	*	*	
108.	*Trichuris muris* (Schrank, 1788) Hall, 1916	*	*	*	

ACANTHOCEPHALA.

(1) (2) (3) (4)

109. *Moniliformis moniliformis* (Bremser, 1811) Tra-
      vassos, 1915   ...   .   *   *   *

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Observations on the Immunity Response in Experimental Ascariasis in Rabbits.

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Introduction.

The use of the Bordet-Gengou complement-fixation test in the investigation of the humoral response in metazoal infestations has resulted in the demonstration of specific antibody production in a number of helminthic diseases. In certain of these diseases, notably schistosomiasis in its various clinical forms (Fairley 1919) and echinococcosis (Fairley 1922), the specific antibody production is sufficiently adequate and constant to render serological tests of very considerable importance in the laboratory diagnosis of these diseases. It is noteworthy that intimate contact between the parasite and the tissues of the host characterises those helminthic diseases associated with a well-marked immunity response. On the other hand, in the hermaphrodite fluke infestations of the bile ducts and intestinal helminthiasis in which the invading helminth is attached merely to the mucous membrane of the intestine, the complement-fixation test is either consistently negative or inconsistently positive and therefore of no real value in the serological diagnosis of the disease.

In the case of infestations with *Ascaris lumbricoides* the definitive habitat of the worm is the small intestine of the host but prior to final localisation in this situation the growing larva follows a definite migratory route through the liver and lungs of the host (Stewart 1918). In consequence of such tissue penetration some form of humoral response in

the nature of specific antibody production sufficiently pronounced to be detected by means of the complement-fixation test is to be anticipated. Consequently the serological investigations recorded in the sequel were carried out over a period which included the migratory phase of the life cycle of *A. megalocephala*, whose life history parallels that of *A. lumbricoides* in man. The experimental animal employed was the rabbit.

While the body-cavity fluid of *Ascaris lumbricoides* has been employed as antigen in the investigation of the humoral response in human Ascariasis (Usami and Kamada, 1921) the results obtained were not regarded as specific to the existence of the disease. It was found that with this antigen positive fixation results were obtained in both Ascariasis and Ankylostomiasis.

Canning (1929) has shown that while tissues may have the same embryonic parentage, their antigenic values may vary widely. For example, while egg and sperm have the same embryonic origin they show wide variation in their specific and group reaction when treated with homologous and heterologous sera. It is believed that the group reaction is more general when the antigen employed is derived from tissue rich in nuclear plasm whereas more specific reactions are obtained when the antigen is prepared from a tissue with a high cytoplasmic content. Thus while the nuclei contain the characteristics common to a group of related species, the more strictly specific materials are to be found in the cytoplasm. It is probable therefore that the results of serological tests in helminthic disease will lend themselves to clearer interpretation if the antigen employed is prepared from tissue of known cytoplasmic and nuclear content. Where antigen is employed from the whole worm obscure and conflicting results are more likely to be obtained. The antigen employed in the present series of tests were prepared from the egg containing uterus of the adult female *A. megalocephala*.

ON THE PREPARATION OF CULTURES OF *A. megalocephala*.

Adult female worms were obtained from the abattoir. The worm was split open and the uteri and ovaries removed from the body cavity. The two uterine branches were cut across about the junction of their anterior and middle thirds and the contents of the anterior third carefully stripped into a large Petri dish. When enough eggs had been

obtained the mass was mixed with a quantity of tap-water and centri-
fuged at low speed for a few minutes to facilitate separation of eggs
and albuminous uterine fluid. After decanting off the supernatant
fluid the eggs in the centrifuge tubes were distributed over a series of
Petri dishes to form a moderately dense emulsion with ordinary tap
water, and placed in the constant temperature room at 22° C. Formalin
was not added to the cultures in order to obviate any possible hardening
influence it might exert on the egg-shell and so retard hatching in the
intestinal tract of the experimental animal.

For the first week the cultures were washed daily. Washing consisted
in fractional centrifugation at low speed using a hand centrifuge. This
repeated centrifugation served not only to rid the aqueous culture
medium of albuminous uterine fluid but had the further effect of throwing
down the fertile eggs more rapidly than the non-fertile and so materially
assisted in concentrating the cultures, as vast numbers of apparently
non-fertile eggs remained in the supernatant fluid and were decanted
off.

SEROLOGICAL INVESTIGATIONS.

Two rabbits were used in the experiment and each received 30·0 c.c.
of a dense aqueous suspension of embryonated ascaris eggs from a culture
45 days old. This volume represented many thousands of ascaris eggs
of which approximately 50%, contained actively motile embryos. The
infective material was thoroughly mixed with a quantity of bran and
oats and fed to the rabbits which had been without food for 24 hours
previously.

Preparation of the Antigen.

A number of female worms were obtained. The uteri and ovaries
were dissected out and placed in a constant temperature room 37·5° C.,
and kept there until desiccation was complete in all cases—a period
of approximately 2 or 3 days.

The desiccated tissues were then thoroughly pulverised in a mortar,
placed in appropriately labelled sterile test-tubes, plugged with cotton-
wool, sealed with paraffin wax and placed in a refrigerator.

An alcoholic extract of powdered uterus was prepared by adding
25·0 c.c. absolute alcohol to 0·25 g. powder and extracting for 24 hours
at 35° C.

During the period of extraction the mixtures were shaken at frequent intervals. At the end of 24 hours the extracts were filtered through No. 2 Chardin filter paper into sterile test-tubes and stored in a refrigerator.

Standardisation of Antigen.

The first step in the standardisation of the antigen consisted in determining the anti-complementary antigenic dose *i.e.*, the highest dilution of antigen capable of fixing 3 M.H.D. of complement.

The following results were obtained :—

Dilution of Antigen.	Undi-luted.	1 : 2	1 : 4	1 : 6	1 : 8	1 : 10
	+	+	±	—	—	—

NOTE : + = no hæmolysis ; — = hæmolysis ; ± = partial hæmolysis.

To obviate as far as possible non-specific reactions in the subsequent complement-fixation tests it was decided to employ the antigen in a 1 : 6 dilution in normal saline.

Standardisation of the diluted Antigen in the Presence of Pooled Normal Rabbit Serum.

The result obtained in the presence of pooled normal rabbit serum may be summarised as follows :—

M.H.D. of Complement.	1	2	3	4	5	6
	+	+	—	—	—	—

THE IMMUNITY RESPONSE.

Subsequent to feeding the rabbits in the manner referred to above the complement-fixation test was carried out at intervals on the serum of the infected animals over a period of five weeks.

The first three tests of the series were performed on pooled serum but as a result of the death of one of the infected animals on the fifth day after it had been fed with embryonated ascaris eggs the serum of only one rabbit could be used in the tests that followed.

The rise in antibody content of the serum during the first five weeks of the disease can readily be appreciated from a consideration of the graph.

The graph was constructed from the figures obtained in a series of complement-fixation tests using alcoholic extract of uterus as antigen. On the ninth day of the disease the serum of the infected animal fixed up to 6 minimum hæmolytic doses of complement, but as the complement
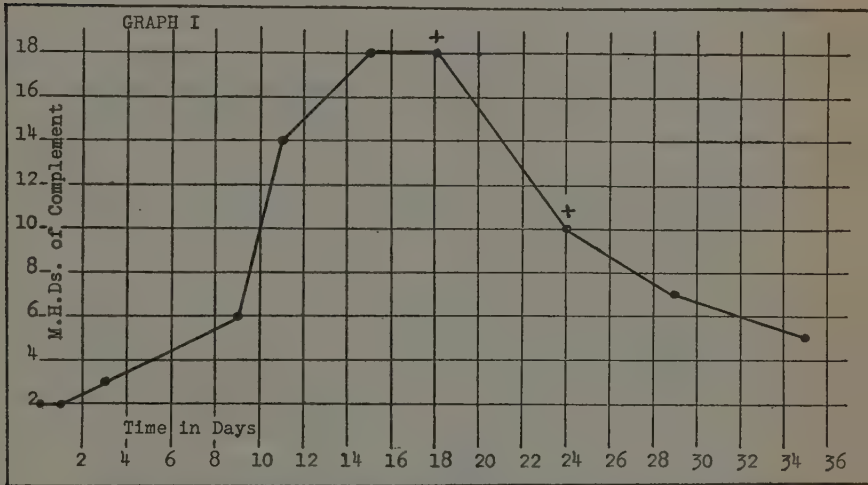
Graphic representation of the antibody content of the serum of a rabbit during first five weeks of an experimental Ascariasis. (Antigen : alcoholic extract of uterus.)

range did not go beyond 6 on this occasion, it is probable that the serum was capable of fixing an even greater amount of complement than the graph indicates. Between the fifteenth and eighteenth days of the disease the antibody content of the serum reached its highest concentration and thereafter began to diminish in amount, until by the end of the fifth week the serum was capable of fixing only 5 M.H.D. of complement.

It would appear therefore that during the migratory phase of the life-cycle of *A. megalocephala* in the rabbit a definite humoral response occurs which is manifested in the serum of the host by the presence

of specific antibody demonstrable by means of the complement-fixation test. The specificity of the antibody and the exact relationship existing between the larval migration and the appearance of antibody in the serum can only be determined by further experimentation. While the results recorded in this preliminary account are suggestive of the occurrence of a definite immunity response in Ascariasis the investigations must necessarily be extended to a larger series of animals before conclusive results can be obtained.

Summary.

1. A preliminary account is given of certain serological investigations carried out on a rabbit fed with the embryonated eggs of *Ascaris megalocephala*.

2. By means of the complement-fixation test it has been shown that a definite immunity response occurs in the first five weeks of the infection.

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On the Eelworm *Heterodera schachtii* as a potential danger to the Sugar-beet Industry in Britain.

ALTHOUGH the first sugar-beet factory was opened in Germany as long ago as 1799, beet growing in Europe was carried out on only a small scale for the next thirty years. Gradually, however, as it was found to be a profitable crop, sugar-beet was more widely cultivated, and other small factories were opened to deal with the increased output of raw material. By 1836 as many as twenty-one factories, in Germany alone, were in operation, although the largest of these were capable of handling only six and a half to eight and a half tons of beet daily. The industry by this time having proved a very profitable one for the agriculturist and industrialist alike, increased acreages of land were yearly devoted to the cultivation of sugar-beet. Improved methods of cultivation resulting in greater tonnage and increased sugar-content, together with an assured market and good prices, further stimulated the industry until, in 1860, one hundred and eighty-four factories were working in Germany. Ten years later the number had risen to three hundred and four, handling about 3,364,760 tons of beet annually.

At this time not only were the beet growers cultivating this valuable crop on every available acre, but in order to wring the maximum profit from the land, the usual agricultural routine of rotation and fallowing as practised at that date was abandoned, and sugar-beet was cropped year after year for eight or ten years in succession in the same fields. This procedure naturally gave every opportunity for diseases and parasites accidentally introduced to become well established and to spread over ever-increasing areas.

As early as 1870 the effects of these ill-advised methods of cultivation began to be felt in the decrease, in both quantity and quality, of the yields.   Chemical analysis of the affected beets showed that these contained a smaller proportion of potassium salts than should normally be present.   This was ascribed to exhaustion of the mineral salts in the land which had been repeatedly used for beet culture.   Unfortunately the resultant decrease in the supply of beets had the effect of raising the prices, so that, instead of fallowing the exhausted land, the growers tried to overcome the mineral deficiency by over-manuring, and beets continued to be grown on the affected land.

In 1878 Liebscher described the condition under the name of " Rübenmudigkeit," or beet-weariness," and the land was known as " beet-weary."   The investigations of Liebscher, and later of Kühn, into this condition showed that the cause of the trouble was due, not to lack of mineral salts (although undoubtedly this condition contributed in many instances to crop failure), but to a tiny eelworm which attacked the roots of the plants.   This organism had already been discovered by Schacht in 1859, and had been named *Heterodera schachtii* by Schmidt in 1871.   Its distribution was so wide and its depredations were so severe that already in 1876 no less than twenty-four factories had been closed down.   Meanwhile, much of the land which was now incapable of growing sugar-beet had been rendered unfit for cereal crops by over-manuring, and areas which, previous to the establishment of beet-culture, had been profitable arable land, now had to be returned to pasture.

Following immediately upon the recognition of the eelworm parasite and its devastating effects in Germany, it was found to be widely distributed also in France, Finland, Holland, Austria-Hungary, Bohemia and Western Russia.   Subsequently is has become established in Sweden, Denmark, Belgium and the Azores, and in 1906 it was discovered in the United States of America, where it now infests large areas of the oldest beet-growing districts of Utah and California.

In addition to attacking sugar-beet, *Heterodera schachtii* has been found to invade the roots of many other plants of economic importance. Amongst the cereals, oats, barley, wheat, rye and maize have been found infected by this parasite, while many vegetables and several of the common fodder crops such as vetches, lucerne, clovers and grasses

have also been recorded as hosts.

In Britain *H. schachtii* was first discovered by Percival in 1895 attacking hops. Since that date it has been recognised on potatoes (Taylor, 1917), peas, wheat, mangolds and cauliflowers. In 1919 beetroot grown between rows of heavily attacked potatoes were reported to show a very slight infection, and in 1927 and 1928 tomatoes were reported to show damage due to attack by *H. schachtii*.

One of the outstanding peculiarities of *H. schachtii* is its power of adaptation to, and specialisation for, individual species of host plant. While in some areas where the parasite occurs numerous varieties of plants will each be attacked if grown in infected soil, in other districts, more particularly those where a single plant species occurs regularly and at short intervals in the crop rotation, the eelworm confines its attack to a single variety of host. This power of specialisation results in the formation of " biological races " or " physiological strains " which more or less completely lose the power of infecting any but the one preferred host plant. In infections of this kind, if the preferred host is withheld from infected land for a sufficient period of time, the eelworm dies out, but a considerable number of years is necessary to effect this clearance, and where land is particularly suited to the culture of some particular crop, considerable financial loss may be sustained by this method of nematode destruction. Moreover, the degree to which the eelworm has lost its power of attacking other hosts always remains a matter of conjecture. For example, the strain of *H. schachtii* attacking potatoes in Lincolnshire can, with difficulty, be made to form a slight infection on tomatoes alone of all cultivated crops. But it has been found to form a natural infection, in isolated instances, on *Chenopodium album*, a common weed, while in Lancashire couch grass has been attacked. Up to the present it has not been determined whether, after reproducing on such a weed for one or more generations, the power of further adaptation to other host plants might not be regained.

As already stated, *H. schachtii* attacks various agricultural crops in this country. Chief among these at the present date is the potato. The earliest record of *H. schachtii* on this host in Britain was made in 1917 when it was recognized by Taylor in Yorkshire. There can be little doubt, however, that even at this time the infection was

widespread, for in 1919 the parasite was recognized both in Cumberland and Cambridgeshire, and in the latter instance so severe was the attack that, in a field where seven hundredweight of seed potatoes were planted, only five and a half hundredweight of the crop were harvested.

Subsequent records show that, in the early post-war years when potato-growing was a profitable and increasing industry, practically all the best potato land in the country became infected. Northumberland, Durham, Cumberland, Lancashire, Yorkshire, Cheshire, Lincolnshire, Staffordshire, Nottinghamshire, Cambridgeshire, Bedfordshire, Anglesey, Sussex, Kent, Surrey, Cornwall and Dorset, have all large or small infected areas, while Wales has several. In Scotland, Ayrshire, Kirkcudbrightshire, Dumbartonshire, East Lothian and Rossshire have all been found to contain areas of *Heterodera schachtii* infection.

No further reports of the eelworm attacking beetroot have been made since 1919 and experimental attempts to produce an infection on this host with the strain specialized on potatoes have failed, both in this country and in Sweden. But in Germany the potato strain has been transmitted to sugar-beet by growing the latter for several successive years in infected soil. As stated above, although *H. schachtii* in Britain appears to be so specialized upon potatoes as to have lost the power of attacking other crops of economic importance, it is by no means certain that under special circumstances the power of attacking some other crop regularly grown in an infected area might not be regained.

Apart from the danger of the widely distributed potato-strains becoming adapted in time to attack sugar-beet, another and more probable source of infection to this host already exists in this country. In 1928 Staniland and Walton discovered a comparatively omnivorous strain of *H. schachtii* attacking mangolds, cauliflowers, and a variety of weeds in Gloucestershire. Experiments made by M. J. Triffitt have shown that this strain readily attacks sugar-beet, forming as intense an infection on this host as on mangolds. Although the infection seems to be confined to two or three fields of a fairly extensive farm, and non-susceptible crops are now being grown on this land, yet the infection is obviously one of long standing and garden crops have been grown and distributed from the infected area, which makes it highly probable that infections too slight as yet to have been detected have already become established in the neighbourhood. It is significant

that although one field is very heavily infested the presence of the nematode was made known only when the annual yield of mangolds had fallen to below one-half of its original figure.

It is interesting to note that mangolds had been cropped on this land on alternate years over a long period, which procedure, as in the sugar-beet industry in Germany and the potato-growing industry in Britain, had doubtless afforded the infection every opportunity of becoming intense. The origin of this infection remains unknown but it seems unlikely that it had arisen as a readaptation of the potato-strain, since potatoes grown experimentally in infected soil were not attacked by the eelworm. It seems probable either that the infection was introduced from an unknown area by imported seed to which a small amount of infected soil was adherent, or that the nematode formed a natural indigenous infection on some species of grass or weed and gradually became adapted to the plants which were cultivated with such regularity. In favour of the second supposition is the fact that a large number of weeds were attacked in the infested field, and these included several varieties of grasses. Moreover, a *Heterodera* of undetermined species has been found forming a natural infection on sea marram grass both in Devonshire and in Scotland. If this unidentified species should prove to be *H. schachtii* it is quite possible that it may have given rise to the various strains recognized in Britain, and it is equally possible that, if intensive sugar-beet cultivation were carried out where it occurs on grasses, a strain of nematode specialized on the beet might result from the same source.

Again there is the possibility, not to be overlooked, that an unspecialized strain attacking mangolds or other field crops may even now be present but unrecognized in some area where sugar-beet culture is already in progress ; for it is only when the depredations of the worm become severe and it is thoroughly well established that expert advice is sought for, leading to diagnosis of the trouble.

These facts point to the desirability of a thorough examination of land by qualified persons before sugar-beet cultivation is begun upon it. Also, since the eelworm is very easily and quickly spread from a single focus of infection over considerable areas in the ordinary routine of cultivation, any crop failures or unsatisfactory yields reported in a district where beet cultivation is being fostered should

be carefully investigated. If eelworm were found in such a case, special measures for isolating the infected region could then be adopted immediately.

From the foregoing remarks and instances the vital importance of allowing a reasonably long rotation of crops becomes abundantly evident. This necessity requires particular stress at the present time of depression in agriculture, for any crop which proves highly profitable will inevitably tend to be grown with considerable frequency, a course which has already proved, both to the beet-growers in Europe and to the potato-growers in this country, to be fraught with disaster.

The methods by which eelworm is spread from a small infected area over a large region are well known. By their own efforts the larvæ can travel considerable distances in a single season, while drainage and cultivation play a large part in the local dissemination of the parasite. Detailed observations in the United States showed that an infected area of one-third of an acre in extent when first noted, had extended in the course of ordinary cultivation to cover an area of two acres in a period of three years. Fragments of soil adhering to implements used in cultivation, to the boots of farm workers and to the feet of animals are sufficient to carry the infection from one field to another. One field in California which had grown beet for thirty-seven years in succession was found in 1907 to be very heavily infected with eelworm. Examination of the surrounding neighbourhood showed that every field within a radius of one mile from this infection contained eelworm also.

The origin of *H. schachtii* in Europe is unknown. It has been suggested that, like *H. radicicola*, a closely related eelworm attacking greenhouse crops in this country, *H. schachtii* is not a native of Europe, but has been imported at some time with exotic plants from the tropics. The recent discovery of *Heterodera* species parasitic upon wild grasses of sand dunes in coastal areas of Britain is, perhaps, evidence against this suggestion. Whatever the origin of the European infection, however, there can be little doubt that the infestation of the beet-growing districts of the United States is the result of an importation of infected material from Europe.

It has been shown that the strain attacking potatoes is conveyed from district to district by the distribution of seed potatoes from infected areas. This is due not only to the presence of eelworms actually living

upon the tubers themselves, but also to the inevitable inclusion of minute quantities of infected soil in the sacks. A supply of " ware " potatoes was obtained by the Institute of Agricultural Parasitology, St. Albans, from an area known to be infected, and after the removal of the tubers the sack was shaken out over white paper. Examination of the dust so obtained showed that a considerable number of eelworm cysts were present. When it is remembered that sacks of seed potatoes are emptied out on to the fields under cultivation, and that each eelworm cyst contains about three hundred eggs capable of giving rise to adult worms in a few weeks, it becomes evident that small foci of infection are constantly being established which, with intensive potato-culture, have every opportunity of spreading and unfitting the land for potato-growing.

In the United States, examinations of sacks of imported sugar-beet seed have revealed that soil is constantly present in these, both loose, in lumps varying in size up to walnut-sized clods, and as dust attached to the irregularities of the outer seed coat. Since this soil must originate from the fields in which the seed beet is grown, too much emphasis can hardly be placed on the importance of securing seed from nematode-free districts, especially for the establishment of the beet industry in a new country such as Britain. The almost universal distribution of the pest in the chief beet-growing countries of Europe must render this difficult, but the supreme importance of guarding against the introduction of so dangerous a parasite should render precautionary measures well worth some initial expense.

It has been shown by American workers that the exposure of beet seed to a dry temperature of from 65° to 70°C. for five to ten minutes actually stimulates the power of germination, while a dry temperature of 65°C., for one minute only, is sufficient to destroy the most resistant stage of the nematode. Since the seed used in England is not obtained from abroad by individual growers, but is distributed through the factories, it should be very easy to ensure that all foreign seed is treated to free it from possible eelworm, and the dry-heat method is sufficiently simple to be applied without incurring any heavy expense.

Finally it should be known that, although research work has been carried out in Germany since 1889 to discover some means of destroying *H. schachtii*, and most of the European powers have financed similar investigations, no chemical means (at other than impossibly exorbitant

cost) have been devised of cleaning infested land once the parasite has become established.   Other methods of ridding infested land of the eelworm are now being tried in Britain, but these are still far from perfect.

Recent advances in the knowledge of *Heterodera schachtii* and its economic importance in agriculture have led the Swedish Government to prohibit the importation of potatoes from countries known to be infected.   This measure has been in force since March 1st, 1929, and steps are also being taken in Sweden to isolate those areas in which the infection is already known, so as to prevent its further spread in that country.

The success of the sugar beet industry recently established in Britain is clearly shown by the yearly increase in the acreage devoted to this crop. In 1930 beets were grown in sixty districts of England and Wales, over a total of approximately 347,105 acres.   Up to the present date no eelworm infections on sugar-beet have been reported, but in view of the facts cited above, the necessity for the organisation of some protective measures should require no further emphasis.

The cultivation of beet on land known to be infected with the strain of *H. schachtii* attacking potatoes should obviously be avoided whenever possible, and in all cases where infected land is used, the roots of the crop should be examined for the parasite during the growing season.   Since beet shows a well marked reaction to the presence of even a slight infection of the nematode, both by flagging in direct sunlight and by the production of numerous lateral rootlets, infections on this crop should be more easily recognised than has been the case with potatoes.   The efficiency of measures to prevent the spread of any outbreak of disease being largely dependent on early diagnosis, a description of the symptoms shown by nematode-attacked plants should be made available to all beet-growers, and all cases of unsatisfactory crops should receive immediate investigation.   These precautionary measures, combined with the use of clean seed, should be sufficient to protect the industry against a pest which has been proved to be one of the most destructive to which the crop is subject.

M. MacM.

IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY.

NOTES AND MEMORANDA.

No. 2.

Hand-list of Helminth Parasites of the Rabbit.

At the request of the National Rabbit Council of Great Britain and the Dominions, this list of parasites of the rabbit has been compiled by the Imperial Bureau of Agricultural Parasitology. In the list are included only those helminth parasites which have been recorded from the common rabbit, *Oryctolagus cuniculus* (=*Lepus cuniculus*). The parasites are grouped under the four main classes : Nematodes, Acanthocephala, Cestodes and Trematodes and are alphabetically arranged within each class. Accepted names are printed in ROMAN CAPITALS, and are followed in each case (where necessary) by a list of synonyms. These synonyms are also cross-referenced in the alphabetical list, where they are printed in lower-case type. The complete original reference to every species (valid or synonymous) will be found in the appended bibliography, where also are included several other references to helminth parasites in this particular host.

TREMATODA.

DICROCŒLIUM DENDRITICUM (Rudolphi, 1819).
    Synonymy.—*Dicrocœlium lanceatum* Stiles and Hassall, 1896.
        Dicrocœlium lanceolatum (Rudolphi, 1803).
        Distoma lanceatum (Stiles and Hassall, 1896).
        Distoma lanceolatum (Rudolphi, 1803).
        Fasciola lanceolata Rudolphi, 1803.
Dicrocœlium lanceatum, *see* Dicrocœlium dendriticum.
Dicrocœlium lanceolatum, *see* Dicrocœlium dendriticum.

Distoma hepaticum, *see* Fasciola hepatica.

Distoma lanceatum, *see* Dicrocœlium dendriticum.

Distoma lanceolatum, *see* Dicrocœlium dendriticum.

FASCIOLA HEPATICA Linnæus, 1758.

　　　Synonymy.—*Distoma hepaticum* (Linnaeus, 1758).

Fasciola lanceolata, *see* Dicrocœlium dendriticum.

CESTODA.

[A complete list of synonyms has been attempted only in the case of adult cestodes, while for larval cestodes only the more important synonyms have been included. Thus, for the well known " hydatid " over 100 synonyms are on record and it seemed superfluous to list them all here ; they can be found in Meggitt, 1924.]

Alyselminthus denticulatus, *see* Cittotænia denticulata.

Alyselminthus pectinatus, *see* Cittotænia pectinata.

ANDRYA CUNICULI (Blanchard, 1891).

　　　Synonymy.—*Anoplocephala cuniculi* Blanchard, 1891.

　　　　　　　　Tænia rhopaliocephala Riehm, 1881.

Andrya wimerosa, *see* Anoplocephala wimerosa.

Anoplocephala cuniculi, *see* Andrya cuniculi.

Anoplocephala pectinata, *see* Cittotænia pectinata.

ANOPLOCEPHALA WIMEROSA (Moniez, 1880).

　　　Synonymy.—*Andrya wimerosa* (Moniez, 1880).

　　　　　　　　Moniezia wimerosa (Moniez, 1880).

　　　　　　　　Tænia wimerosa Moniez, 1880.

Bothriocephalus liguloides, *see* Diphyllobothrium mansoni.

Bothriocephalus mansoni, *see* Diphyllobothrium mansoni.

CITTOTÆNIA CTENOIDES (Railliet, 1890).

　　　Synonymy.—*Cittotænia leuckarti* (Riehm, 1881).

　　　　　　　　Ctenotænia leuckarti (Riehm, 1881).

　　　　　　　　Dipylidium leuckarti Riehm, 1881.

　　　　　　　　Moniezia leuckarti (Riehm, 1881).

　　　　　　　　Tænia ctenoides Railliet, 1890.

　　　　　　　　Tænia leuckarti (Riehm, 1881).

CITTOTÆNIA DENTICULATA (Rudolphi, 1804).

> Synonymy.—*Alyselminthus denticulatus* (Rudolphi, 1804) [in part].
> *Cittotænia latissima* Riehm, 1881.
> *Ctenotænia goezei* (Baird, 1853).
> *Ctenotænia latissima* (Riehm, 1881).
> *Dipylidium latissimum* (Riehm, 1881).
> *Moniezia denticulata* (Rudolphi, 1804) [in part].
> *Moniezia goezei* (Baird, 1853).
> *Moniezia latissima* (Riehm, 1881).
> *Tænia denticulata* Rudolphi, 1804.
> *Tænia goezei* Baird, 1853.
> *Tænia latissima* (Riehm, 1881).

Cittotænia latissima, *see* Cittotænia denticulata.

Cittotænia leuckarti, *see* Cittotænia ctenoides.

CITTOTÆNIA PECTINATA (Goeze, 1782).

> Synonymy.—*Alyselminthus pectinatus* (Goeze, 1782).
> *Anoplocephala pectinata* (Goeze, 1782).
> *Ctenotænia pectinata* (Goeze, 1782).
> *Dipylidium pectinatum* (Goeze, 1782).
> ? *Halysis pectinata* (Goeze, 1782).
> *Moniezia pectinata* (Goeze, 1782).
> *Tænia acutissima* Pallas, 1781 [in part].
> *Tænia cuniculi* Baird, 1853.
> *Tænia leporina* Limbourg, 1767.
> *Tænia pectinata* Goeze, 1782.

Cœnurus cerebralis, *see* Multiceps multiceps.

Cœnurus cerebralis leporis-cuniculi, *see* Multiceps serialis.

Cœnurus serialis, *see* Multiceps serialis.

Ctenotænia goezei, *see* Cittotænia denticulata.

Ctenotænia latissima, *see* Cittotænia denticulata.

Ctenotænia leuckarti, *see* Cittotænia ctenoides.

Ctenotænia pectinata, *see* Cittotænia pectinata.

Cysticercus echinococcus, *see* Echinococcus granulosus.

Cysticercus pisiformis, *see* Multiceps serialis and Tænia pisiformis.

Cysticercus polycephalus, *see* Multiceps serialis.

Cysticercus serratus, *see* Tænia pisiformis.

Dibothrium mansoni, *see* Diphyllobothrium mansoni.

Diphyllobothrium mansoni (Cobbold, 1883).

> Synonymy.—*Bothriocephalus liguloides* Leuckart 1886.
> *Bothriocephalus mansoni* (Cobbold, 1883).
> *Ligula mansoni* Cobbold, 1883.
> *Plerocercoides mansoni* (Cobbold, 1883).
> *Sparganum mansoni* (Cobbold, 1883).
> *Dibothrium mansoni* (Cobbold, 1883).

Dipylidium latissimum, *see* Cittotænia denticulata.

Dipylidium leuckarti, *see* Cittotænia ctenoides.

Dipylidium pectinatum, *see* Cittotænia pectinata.

Echinococcus cysticercus, *see* Echinococcus granulosus.

Echinococcus granulosus (Batsch, 1786).

> Synonymy.—*Cysticercus echinococcus* (Zeder, 1803).
> *Echinococcus cysticercus* Daniels, 1910.
> *Echinococcus multilocularis* Leuckart, 1863.
> *Tænia echinococcus* (Zeder, 1803).

Echinococcus multilocularis, *see* Echinococcus granulosus.

Halysis pectinata, *see* (?) Cittotænia pectinata.

Hydatigena cordata, *see* Tænia pisiformis.

Hydatigena pisiformis, *see* Tænia pisiformis.

Hydatis cordata, *see* Tænia pisiformis.

Hydatis pisiformis, *see* Tænia pisiformis.

Ligula mansoni, *see* Diphyllobothrium mansoni.

Moniezia denticulata, *see* Cittotænia denticulata.

Moniezia goezei, *see* Cittotænia denticulata.

Moniezia latissima, *see* Cittotænia denticulata.

Moniezia leuckarti, *see* Cittotænia ctenoides.

Moniezia pectinata, *see* Cittotænia pectinata.

Moniezia wimerosa, *see* Anoplocephala wimerosa.

Multiceps multiceps (Leske, 1780).

> Synonymy.—*Cœnurus cerebralis* (Batsch, 1786).
> *Tænia cerebralis* (Batsch, 1786).
> *Tænia cœnurus* (Tschudi, 1837).
> *Tænia multiceps* Leske, 1780.

Multiceps serialis (Gervais, 1847).

> Synonymy.—*Cœnurus cerebralis leporis-cuniculi* Diesing, 1863.
> *Cœnurus serialis* Gervais, 1847.
> *Cysticercus pisiformis* (Bloch, 1780) [in part].

Cysticercus polycephalus Reinitz, 1885.

Tænia serialis (Gervais, 1847).

Plerocercoides mansoni, *see* Diphyllobothrium mansoni.

Sparganum mansoni, *see* Diphyllobothrium mansoni.

Tænia acutissima, *see* Cittotænia pectinata.

Tænia cerebralis, *see* Multiceps multiceps.

Tænia cœnurus, *see* Multiceps multiceps.

Tænia ctenoides, *see* Cittotænia ctenoides.

Tænia cuniculi, *see* Cittotænia pectinata.

Tænia denticulata, *see* Cittotænia denticulata.

Tænia echinococcus, *see* Echinococcus granulosus.

Tænia goezei, *see* Cittotænia denticulata.

Tænia hydatigena pisiformis, *see* Tænia pisiformis.

Tænia latissima, *see* Cittotænia denticulata.

Tænia leporina, *see* Cittotænia pectinata.

Tænia leuckarti, *see* Cittotænia ctenoides.

Tænia multiceps, *see* Multiceps multiceps.

Tænia pectinata, *see* Cittotænia pectinata.

TÆNIA PISIFORMIS (Bloch, 1780).

> Synonymy.—*Cysticercus pisiformis* (Bloch, 1780) [in part].
> *Cysticercus serratus* (Goeze, 1782).
> *Hydatigena cordata* Batsch, 1786.
> *Hydatigena pisiformis* (Bloch, 1780).
> *Hydatis cordata* (Batsch, 1786).
> *Hydatis pisiformis* (Bloch, 1780).
> *Tænia hydatigena pisiformis* (Bloch, 1780) Goeze, 1782.
> *Tænia serrata* Goeze, 1782.

Tænia rhopaliocephala, *see* Andrya cuniculi.

Tænia serialis, *see* Multiceps serialis.

Tænia serrata, *see* Tænia pisiformis.

Tænia wimerosa, *see* Anoplocephala wimerosa.

NEMATODA.

Ascaris veligera, *see* Dermatoxys veligera.

CAPILLARIA LEPORIS (Diesing, 1851).
> Synonymy.—*Filaria pulmonalis* Frölich, 1802 [in part].
>> *Trichosoma leporis* Diesing, 1851.

DERMATOXYS VELIGERA (Rudolphi, 1819).
> Synonymy.—*Ascaris veligera* Rudolphi, 1819.

Filaria leporis pulmonalis, *see* Synthetocaulus commutatus.

Filaria pulmonalis, *see* Capillaria leporis and Synthetocaulus commutatus.

GONGYLONEMA NEOPLASTICUM (Fibiger and Ditlevsen, 1914).
> Synonymy.—*Spiroptera neoplastica* Fibiger and Ditlevsen, 1914.

GRAPHIDIUM STRIGOSUM (Dujardin, 1845).
> Synonymy.—*Spiroptera leporum* Moniez, 1880.
>> *Strongylus leporum* (Moniez, 1880).
>> *Strongylus strigosus* Dujardin, 1845.

HEPATICOLA HEPATICA (Bancroft, 1893).
> Synonymy.—*Trichocephalus hepaticus* Bancroft, 1893.

NEMATODIRUS LEPORIS Chandler, 1924.

OBELISCOIDES CUNICULI (Graybill, 1923).
> Synonymy.—*Obeliscus cuniculi* Graybill, 1923.

Obeliscus cuniculi, *see* Obeliscoides cuniculi.

Oxyuris ambigua, *see* Passalurus ambiguus.

PASSALURUS AMBIGUUS (Rudolphi, 1819).
> Synonymy.—*Oxyuris ambigua* Rudolphi, 1819.

Rhabdonema longum, *see* Strongyloides papillosus.

Spiroptera leporum, *see* Graphidium strigosum.

Spiroptera neoplastica, *see* Gongylonema neoplasticum.

Strongyloides longus, *see* Strongyloides papillosus.

STRONGYLOIDES PAPILLOSUS (Wedl, 1856).
> Synonymy.—*Rhabdonema longum* Grassi, 1855.
>> *Strongyloides longus* (Grassi, 1885).
>> *Trichosoma papillosum* Wedl, 1856.

Strongylus commutatus, *see* Synthetocaulus commutatus.

Strongylus leporum, *see* Graphidium strigosum.

Strongylus retortæformis, *see* Trichostrongylus retortæformis.

Strongylus rufescens, *see* Synthetocaulus rufescens.

Strongylus strigosus, *see* Graphidium strigosum.

SYNTHETOCAULUS COMMUTATUS (Diesing, 1851).

    Synonymy.—*Filaria leporis pulmonalis* Frölich, 1802 ; Rudolphi, 1819.

        Filaria pulmonalis Frölich, 1802 [in part].

        Strongylus commutatus Diesing, 1851.

SYNTHETOCAULUS RUFESCENS (Leuckart, 1865).

    Synonymy.—*Strongylus rufescens* Leuckart, 1865.

Trichina spiralis, *see* Trichinella spiralis.

TRICHINELLA SPIRALIS (Owen, 1835).

    Synonymy.—*Trichina spiralis* Owen, 1835.

Trichocephalus hepaticus, *see* Hepaticola hepatica.

Trichocephalus leporis, *see* Trichuris leporis.

Trichocephalus unguiculatus, *see* Trichuris leporis.

Trichosoma leporis, *see* Capillaria leporis.

Trichosoma papillosum, *see* Strongyloides papillosus.

TRICHOSTRONGYLUS AFFINIS Graybill, 1924.

TRICHOSTRONGYLUS RETORTÆFORMIS (Zeder, 1800).

    Synonymy.—*Strongylus retortæformis* Zeder, 1800.

TRICHURIS LEPORIS (Frölich, 1789 ; Rudolphi, 1809).

    Synonymy.—*Trichocephalus leporis* Frölich, 1789 ; Rudolphi, 1809.

        Trichocephalus unguiculatus Rudolphi, 1809.

ACANTHOCEPHALA.

ECHINORHYNCHUS CUNICULI Diesing, 1851.

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On the occurrence of Gapeworms in Nestling Starlings and adult Fowls.

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HELMINTHS IN NESTLING STARLINGS.

TAYLOR (1928), in an attempt to infect starlings with the gapeworm, was able to infect six starlings out of fifteen which had been dosed, nine of which died before any observations could be made. The value of this experiment is, however, somewhat doubtful owing to the possibility of previous infection in the starlings experimented with, and the author concludes that in one bird, such was the case, owing to the size of the worms found.

At the suggestion of Professor Leiper four young starlings were taken from a nest in May of this year and placed in a cage near an open window at a spot close to the old nest. By adopting this method the parent birds continued to feed their young through the bars of the cage. It is not possible to give the age of the young birds when they were brought into captivity and although none of them had left the nest previously they appeared to be almost fully fledged.

We intended to rear these starlings with the object of carrying out some experiments on *Syngamus trachea* and to obtain further data on the importance of this host as a spreader of " Gapes " in chickens and other domestic birds.

It was hoped, by bringing young starlings, which had never left the nest, into captivity, to obviate the possibility of any previous infection, at any rate from " Gapes." Unfortunately this was not the case and

neither was it found possible to keep the birds alive longer than about three weeks. Two of the young birds died within a few days and through an oversight they were, unfortunately, not examined for worms. A third died after a week in captivity and the helminthic infection found was surprising considering that the bird had not been exposed to infection outside the nest.

Three pairs of *Syngamus trachea* were found in the trachea, one of which was fully developed and contained eggs which were ready for oviposition. The other two specimens were slightly smaller and not fully matured.

In addition, this starling harboured several young specimens of tapeworms belonging to the genus *Hymenolepis*. There were also present three specimens of *Capillaria ovopunctata* which were almost mature and two young stages of an ascarid type of worm—probably *Porrocæcum ensicaudatum*.

The fourth bird from the same nest lived for a further period of two weeks and during this time eggs of Syngamus were observed in its droppings. A post-mortem examination of this bird showed one fully matured pair of Syngamus in the trachea ; a large number of young stages of Hymenolepis species ; four adult *C. ovopunctata* and four almost mature *P. ensicaudatum*.

Four young starlings from another nest, which was situated within a short distance of the one referred to above, were found to be entirely free from Syngamus although the other species of worms recorded from the birds in the first nest were present. In one of these nestlings as many as 67 heads of tapeworms were found.

The above observations are placed on record owing to their interest in suggesting the method of dissemination of the gapeworm in the starling. It is well known that starlings are particularly clean in their nesting habits, and it is unlikely that the worms would be carried, to any considerable extent, directly to the nestlings by the parents. It was often observed that earthworms formed a considerable part of the food of the young birds and considering the role played by earthworms as passive carriers of the gapeworm it seems probable that the infection was derived from this source. Similarly, in the case of Hymenolepis, the infection would undoubtedly arise through an intermediate host carried as food for the nestlings.

Starlings as Distributors of "Gapes" in Chickens.

The finding of a high percentage of Syngamus infection in starlings in the Aberystwyth area of Wales by Lewis (1925 ; 1926) has brought to the fore the question of the importance of this host as a disseminator of "Gapes" in Chickens. In support of this finding by Lewis the present writer observed infections amounting to over thirty per cent., in starlings caught in the area surrounding the Institute of Agricultural Parasitology in Hertfordshire.

It was shown by Leiper (1926) that an experimental infection of chickens by the starling gapeworm could be obtained. Taylor (1928) in an extensive study of the starling gapeworm when transferred to chickens, found that the first passage through the chick produced only very light infections. He was, however, able to produce heavy infections by using the starling strain after it had made one passage through the chick.

As a result of these experiments this author finally considers it probable " that the strain of *Syngamus trachea* of starlings used in these experiments would be harmless to chickens under natural conditions." Taylor's experiments certainly do show considerable evidence in favour of the presence of a physiological strain of *S. trachea* in the starling but it does not seem clear from his results how he arrives at the conclusion quoted above. His success in experiment No. 3, when five out of eight chicks died of " Gapes " which had originally been obtained from starlings, would make it seem improbable that *S. trachea* of starlings is harmless to chickens. Flocks of starlings are often found on chicken pens and it would seem probable that the ground would soon become contaminated with Syngamus eggs of starling origin which had made one or more passages through chickens or even, occasionally, through adult fowls.

Syngamus in Adult Fowls.

Owing to the fact that the gapeworm is rarely seen in adult fowls, although common in young chicks, it is held that Syngamus is not a natural parasite of this host. In the turkey, however, it is often found in adult birds and this host is therefore considered as the chief factor in the dissemination of " Gapes."

Ransom (1921) succeeded in some instances in infecting adult fowls and in one case obtained an infection in a hen exposed to infested ground. He further suggested the possibility that when fowls become old and debilitated their susceptibility to gapeworms might tend to increase, adding, however, that the worms usually find great difficulty in maintaining themselves in adult birds.

In this connection it is of interest to record a case of gapeworm infection in a hen at this Institute. A batch of year old hens were bought in Essex and placed in a pen at Winches Farm in April last. No fowls had previously occupied this pen for at least six years and there was no chance of contamination from other fowls kept on the farm.

Early in May one of the hens began to show signs of weakness and was therefore isolated. It remained in a droopy condition for about two weeks and then died. Fæcal examinations were made frequently during these two weeks and revealed the presence of *Ascaridia, Heterakis* and *Capillaria*. On the 15th of May, two days before the hen died, numerous eggs of *Syngamus* were observed in the fæces. The post-mortem examination revealed twelve pairs of *Syngamus trachea* in the lower half of the trachea. The female worms measured from 15 mm. to 20 mm.

It is not clear in this case where the infection had been picked up unless it is assumed that this had taken place before the hens were introduced to the farm. One must not, however, exclude the possibility of these gapeworms being of starling origin and their development in the hen being greatly assisted by the loss of resistance due to its emaciation.

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Some Observations on Experimental Ascariasis in Pigs.

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During the latter half of 1930 and the beginning of the present year some miscellaneous experiments on Ascaris in pigs were carried out at the Institute of Agricultural Parasitology by Professor Leiper and myself. Although these experiments were of a preliminary nature it was thought that some of the observations made during their course might be of interest to other workers in this field and they are, therefore, placed on record.

Experiment I.

In the first experiment, four two-month old pigs taken from two litters born on the same day were infected as follows :—Three of these (Nos. 8, 9, 17) were each fed with a large number of embryonated eggs of *Ascaris lumbricoides* from the pig, and the other pig (No. 5) was fed with embryonated eggs of *Parascaris equorum.*

The result of this experiment was entirely negative in all four pigs. None of the symptoms associated with the migration of larvæ into the liver and lungs were observed during the following days and although the fæces was examined at different times for some weeks after the experiment, no eggs were found.

Experiment II.

A month later pig No. 5 was again fed with embryonated eggs of *P. equorum* and the result was, as before, negative.

Experiment III.

On October 9th, 1930, when the pigs were five months old, they were fed again with embryonated eggs as recorded for the first experiment, *i.e.*, Nos. 8, 9 and 17 with eggs of *A. lumbricoides* and No. 5 with eggs of *P. equorum*. As there was a fair quantity of material available, another pig, No. 6, from the same litters was also fed with eggs of *A. lumbricoides*. An examination of the fæces of this latter animal showed that it had already picked up a natural infection of *A. lumbricoides*.

Each pig received a much larger quantity of eggs in this experiment than in the previous one, and pig No. 6, in particular, received approximately twice as many eggs as the other three.

Pig No. 8, which had now received three heavy doses of *P. equorum* eggs at different times, again showed no symptoms due to a possible migration of the larvæ, and an examination of its fæces at a later date showed no eggs. It would thus appear that *P. equorum* can not develop in the pig, neither do the larvæ go through their migration in this host, at any rate, in sufficient numbers to produce recognisable symptoms of disease.

With regard to the other three animals which had received eggs of *A. lumbricoides* it became evident on the following day that an infection had taken place. The animals showed little inclination for food and remained huddled up in the litter ; No. 6, in particular showed considerable distress with laboured breathing 48 hours after the infection and died within 60 hours. A post-mortem examination of this pig showed an intense congestion of the lungs, while numerous larvæ were found both in the liver and the lungs. In the intestine 6 adult *A. lumbricoides* were found which had been acquired naturally as this animal had not previously been subjected to experimental infection.

Of the remaining experimental animals, Nos. 9 and 17 died of pneumonia in 6 days after infection and each showed large numbers of larvæ in the lungs and liver. Pig No. 8 died on the following day and in this case also a large number of larvæ were found.

It is interesting to note that No. 6 withstood the infection for less than 60 hours while the other three pigs remained alive for about a week. As already stated, No. 6 received a much larger number of eggs than the other pigs and the intense hæmorrhage caused by the migrating larvæ would appear to have caused its early death. The other animals

were probably able to withstand this initial damage to the tissues but succumbed to the pneumonia which followed.

Experiment IV.

In a further experiment the larvæ obtained from the lungs and liver of pig No. 8 were used to infect three pigs from another litter. These animals were approximately 5 months old on October 17th when the experiment was carried out.
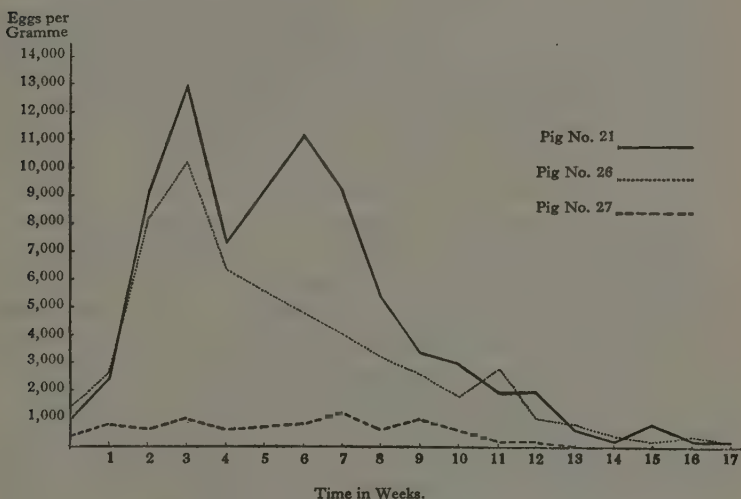
Graph showing results obtained from *Experiment IV*.

One pig (No. 21) was fed with half the infected lung from pig No. 8. The remaining half of the lung, together with the liver, were minced, placed in muslin, and then suspended in normal saline which was kept at 37° C. to 40° C. The larvæ thus obtained were then divided between two pigs (Nos. 26 and 27) from the same litter as No. 21.

As one would expect there were no symptoms following infection in these animals as the larvæ had already completed the migratory part of their life-history in another pig. As each of these pigs had already acquired a natural infection it was impossible to say with certainty how soon the worms reached maturity, by an examination of the fæces.

Weekly egg counts were, however, made commencing on the fourth week after the pigs were infected and these were continued for about five months. Egg counts were made by the dilution method used by Stoll (1930) in making counts of eggs in sheep fæces. The only modification adopted by the present writer being in the use of 5 gm. of fæces instead of 10 gm. as used by Stoll and, consequently, the dilution by N/10 NaOH being made up to 150 cc. instead of 300 cc.

The accompanying graph shows the weekly egg counts obtained for each of the three pigs.

Although these pigs were five months old and already harboured a natural infection, it is obvious from the sharp rise in the number of eggs from the fourth week to the eighth week after feeding, that an experimental infection had taken place, at least in pigs Nos. 21 and 26. After about the eighth week there is a more or less gradual diminution in the number of eggs until it almost vanishes in the twenty-second week when the experiment was terminated. In the case of pig No. 27 it will be seen from the graph that the infection remained at a low level until the eighteenth week and then disappeared. Although this latter animal had received approximately the same number of larvæ as pig No. 26 there was no marked increase in the number of eggs as one found in the other two pigs. This may have been due to the fact that No. 27 was a heavier and stronger pig than the others when the experiment was started and may have, therefore, set up a greater resistance to the infection. It is of interest to note that the low infection in No. 27 was maintained until the eighteenth week of the experiment although the animal appeared to be in a good thriving condition.

A feature observed about the fifteenth week after infection was the number of unfertile eggs in the fæces of each pig, and from the sixteenth week onward the few eggs that were obtained were all in this condition. When Nos. 21 and 27 were slaughtered three weeks after the experiment terminated, there were no worms found in No. 27 but in No. 21, two female Ascaris had remained and both these contained unfertile eggs.

The presence of unfertile eggs during the last few weeks of the experiment and when the infection was gradually diminishing seems to suggest that the longevity of the males is less than that of the females, and further, that the store of spermatozoa in the female can become exhausted before its egg laying capacity. The fact that each of the three pigs passed

unfertile eggs would tend to discount the possibility of these unfertile females being the result of a small natural infection (picked up towards the end of the experiment) which did not happen to contain males.

In addition to the egg counts, weekly weighings of these pigs were made, but the figures obtained do not indicate any correlation between the gain in weight and the intensity of infection as judged by egg counts. It is true that No. 27 made the greatest gain in weight and had also the fewest worms of the three pigs. At the end of the experiment this pig had reached a weight of 148 lbs. No. 21, on the other hand, although very unthrifty when infected and weighing slightly less than No. 26, soon showed a much more rapid increase in weight than the latter in spite of its heavier infection. No. 21 weighed 106½ lbs. and No. 26 85½ lbs. at the end of the experiment.

Experiment V.

The remaining pig (No. 26) from the above experiment was subjected to a further infection on April 16th, 1931. This animal was now about 10 months old but had remained rather stunted in growth. It was fed with a large dose of embryonated eggs of *A. lumbricoides* from an old culture containing a large number of non-viable eggs.

During the first 48 hours after infection the pig became very uneasy and showed no desire for food. On the fourth and fifth day it appeared to be brighter but afterwards it gradually weakened and died on the ninth day. Post-mortem examination showed large numbers of larvæ in the lung accompanied by pneumonia. The larvæ did not show any movement although a fair number had already reached the small intestine. This pig also harboured two adult female Ascaris containing unfertile eggs.

Age Resistance and Immunity.

As shown by Sandground (1929), our knowledge of the bionomics of the pig Ascaris is as yet far from complete owing to the difficulty of establishing infections under normal conditions. The success obtained in some of the experiments recorded in this paper may possibly have been due to the exceptionally large number of eggs fed to each animal and this fact must be taken into consideration in drawing conclusions from the results obtained.

Further, in two of the pigs in particular, Nos. 21 and 26, the writer was dealing with animals that were already unthrifty and this may have influenced the resistance put to the disease.

In reviewing the experiments one may point out, however, certain results which appear to have a bearing on the question of age resistance and acquired immunity.

It will be seen that in Experiment III the pigs were five months old when the experiment was carried out and yet these animals were, in all cases, unable to withstand the infection. Further, pig No. 6 in this experiment already harboured at least six adult Ascaris when it was dosed so that an immunity arising out of a previous infection is certainly not indicated here.

Again, if the sharp rise in egg counts as shown in the accompanying graph can be taken as an indication of a new infection, it will be seen that an infection, superimposed on an already existing natural infection, was established in at least two out of the three pigs fed with Ascaris larvæ.

Finally, one of the pigs from the above experiment, although it had harboured Ascaris for the greater part of its life, quickly succumbed to a new experimental infection, and this when at an age of ten months.

It has been held (Ransom, 1922) that, when pigs are about four months old they acquire an age resistance to Ascaris or, at least, that the disturbance in the host is not great if any larvæ do succeed in migrating. The evidence in favour of an age resistance or of an acquired immunity is, however, far from conclusive and the present experiments, although the results might be objected to on the grounds stated above, tend to support this view. The more extensive researches on human Ascaris also show no clear indication of an immunity or an age resistance. Otto (1930) from his investigations on human Ascaris puts forward the interesting suggestion that there is " an almost complete turnover in the worm burden each year." Bearing on this suggestion the results obtained in Experiment IV are of interest in that they give some indication of the duration of an infection. The larvæ were fed to the pigs on October 17th, 1930, and in eighteen weeks one pig had entirely lost its infection ; the other two pigs had only two worms remaining at the end of twenty-two weeks. As already stated these remaining worms had only been producing unfertile eggs for some time previously.

An experiment to test out this question of longevity is not an easy matter owing to the difficulty of preventing the animals from picking up fresh infections. As far as the egg counts in Experiment IV are concerned there is no evidence that this was taking place although the pigs had ample opportunity of picking up eggs. It is questionable whether the egg counting method adopted would indicate slight increases in the worm burden. The fact, however, that in the three pigs this worm burden was almost entirely lost in twenty-two weeks, although the chance of reinfection was considerable, does suggest the possibility of a self cure or of an acquired immunity being present. Such an immunity would, however, be of very short duration since one of the pigs died soon after as the result of a new infection.

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A Case of Carbon tetrachloride Poisoning in Southern Rhodesia.

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SINCE the introduction of carbon tetrachloride for the treatment of the hookworm infestations of man it has been ascertained that in certain conditions fatal poisoning may follow oral administration of the drug. If carbon tetrachloride is given in cases of alcoholic cirrhosis of the liver, or if alcohol is taken immediately after the drug, severe gastro-intestinal symptoms are to be anticipated with death in two or three days. Davis (1924) showed that in dogs the toxicity of the drug was intimately associated with certain dietetic factors. He found that a high carbohydrate diet enabled the liver to withstand relatively large doses of the drug. High protein diets also protected the liver against injury (although less efficiently than carbohydrate) but an " all-fat " diet was invariably associated with extensive damage to the hepatic parenchyma. Lambert (1923) while carrying out hookworm treatment on a large scale in Fiji found that where a patient was heavily infested with *Ascaris lumbricoides* as well as with hookworm it was unwise to exhibit carbon tetrachloride without first getting rid of the ascarids. The drug, apparently, increased the activity of the ascaris worms which formed themselves into conglomerate masses sufficiently large to produce fatal intestinal obstruction or fatal results might be produced in other ways either from the mechanical presence of the worms or from unknown toxic factors. Deficiency in the blood calcium reserve has been shown recently to predispose to carbon tetrachloride poisoning (Minot 1927). It has been suggested (Lamson, Minot and Robbins 1928) that the damage to the liver cells is associated with a rise in the serum bilirubin which enters into combination with the ionic blood calcium. Thus, while the total blood calcium may be within normal limits or even higher than normal, the amount of available calcium in the blood is insufficient for the body needs and

thus the cholæmia is complicated by a condition of acute calcium deficiency. It is also to be expected that in cases already suffering from extensive hepatic disease the administration of carbon tetrachloride must necessarily be a risky procedure. Impurities in the drug such as carbon disulphide and carbonyl chloride were believed to be responsible for some of the earlier fatalities.

From time to time cases of carbon tetrachloride poisoning occur in which none of these factors operate. Such cases appear to be examples of idiosyncrasy to the drug and from the available data it would seem that the following example of carbon tetrachloride poisoning falls into this category.

The patient was an adult male Native who came originally from Nyasaland. He was admitted to the Salisbury Hospital, Southern Rhodesia, on account of a diffuse, painful swelling of the left lower extremity not associated with any systemic disturbances. No other abnormalities were found in the course of a routine physical examination.

Examination of the fæces showed that the patient harboured a number of hookworms and it was decided that anthelmintic treatment should be given. No other helminths were present. Preliminary treatment consisted in giving the patient rice and bread and milk for his evening meal in place of the usual preparation of mealie meal (maize).

At 7 a.m. the following day he was given, by mouth, 3·0 cc. of a fresh preparation of carbon tetrachloride in a gelatin capsule and this was followed by magnesium sulphate at 9 a.m. A stool was passed in the course of the morning and from it sixteen Necators were recovered. By mid-day the patient was observed to be unusually drowsy and lethargic. He experienced marked vertigo whenever he raised his head from the pillow and although circumstances prevented a detailed study of the clinical aspect of the case it appears that the somnolence continued throughout the rest of the day. Vomiting occurred in the early part of the evening and the patient was obviously seriously ill. He eventually lapsed into coma and died at 5 a.m. the following morning, *i.e.*, 22 hours after the administration of the carbon tetrachloride.

The lungs were in the main œdematous with well marked hypostatic congestion at either base. The bronchi contained a blood-stained sero-mucous fluid. Some fibrous adhesions were present over the right-base posteriorly.

The myocardium was flabby and the heart, as a whole, dilated. The liver was noticeably enlarged and of a pale, unhealthy colour, with a darkish mottling present on the surface and throughout the organ generally.

The spleen was slightly enlarged, dark and congested.

Two minute hæmorrhages were observed in the capsule of the right kidney. The capsule stripped readily in both cases. The renal tissue was pale in appearance and presented a dull surface on section.

No naked eye changes were detected in the supra-renal glands. The mucous membrane of the upper reaches of the small intestine was congested but otherwise no abnormalities were found in the intestinal tract. Portions of liver, lung and kidney were selected for microscopical examination.

Liver. The liver parenchyma was diffusely involved but in conformity with the usual findings in cases of carbon tetrachloride poisoning the lesions presented a distinct zonal distribution in regard to the liver lobule. This could readily be appreciated on examination with the low power of the microscope. At the periphery of each lobule and in close proximity to the portal tracts a number of liver cells could invariably be found showing only slight degrees of cloudy swelling. Cells situated a short distance in from the periphery and cells of the mid-zonal area showed much vacuolation of their cytoplasm and an indeterminate cell outline while the central cells were so extensively damaged and autolysed as to give the centre of the lobule a loose reticular appearance. In those areas characterised by extensive damage to the parenchyma, the liver sinusoids were intensely congested and showed a tendency to bulge outwards and replace the damaged liver cells thus giving a hæmorrhagic appearance to parts of the section.

Kidneys. No evidence of damage to the glomeruli could be found. Degenerative changes, however, were present in the epithelium of the more distal part of the tubules. Foci of intense congestion and actual hæmorrhages were also present.

Lungs. The lung tissue as a whole was intensely congested with, in places, a fluid exudate present in the alveoli. The bronchioles also contained a fluid exudate with which a few leucocytes and desquamated epithelial cells were mingled.

COMMENTARY.

This case is of interest in that there was no feature in the physical condition of the patient or in the laboratory findings which might be regarded as predisposing to carbon tetrachloride poisoning. The swollen limb, whilst of unknown ætiology, can hardly be regarded as a predisposing factor as the condition was not associated with any general systematic disturbance and as several other cases with the same condition had been treated successfully with carbon tetrachloride on previous occasions. The patient's diet had been so arranged that no drain occurred on the glycogen reserves of the liver before the administration of the drug and no fats or oils were ingested after the dose had been taken.

No ascarids were present in the intestine, and, as the post-mortem findings showed, there had been no pre-existing disease of the liver.

Furthermore, since the case presented none of the clinical features of a rapidly produced deficiency in the blood calcium in the terminal phases of the illness the possibility of a deficient calcium reserve prior to treatment is practically excluded.

Finally, the drug was stated to be fresh and, as two other natives were given a similar dose, under similar conditions on the same day without harmful effects the presence of impurities in the drug is adequately excluded.

In the sense, therefore, that idiosyncrasy is an unusual reaction to a drug for which no reasonable explanation can be offered the present case may be regarded as an example of idiosyncrasy to carbon tetrachloride on the part of an African native.

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On Two New Species of *Enterobius* from the Monkey *Lagothrix humboldtii.*

By J. J. C. BUCKLEY, M.Sc.

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THE material here described was obtained from the large intestine of a Humboldt's Woolly Monkey (*Lagothrix humboldtii*) which died at the Zoological Gardens, London, about a month after it had been received there. In addition to the *Enterobius* infection there was a severe infection with *Ascaris lumbricoides*, involving both liver and small intestine. A single specimen of *Necator* was present, and along with the *Enterobius* were two immature female worms of doubtful identity, which are also described in this paper.

A superficial examination of the Oxyurids shewed them to be closely related to *Enterobius atelis* Cameron, 1929, particularly with regard to the indistinct lips, the grouping of the circumoral papillæ, and the presence of œsophageal teeth, features which hitherto have been peculiar to Cameron's species. A more detailed study of the worms revealed the fact that, not only was it impossible to identify them as *E. atelis*, for reasons to be set forth later, but that the material was composed of two distinct species, differing from one another especially in the structure of the œsophageal teeth.

Whilst it was a comparatively simple matter to differentiate the females of the two species and also the males, on this basis, the difficulty arose however, of combining correctly the males and females of the same species. The teeth proved valueless in this respect, for sexual dimorphism apparently exists in regard to this character, there being two teeth in the females and three in the males, and in no case could any resemblance between male and female teeth be noted. In the cephalic vesicle alone was any clue afforded, for its shape was found

to be characteristic of each species and common to two sexes. On this evidence the males and females were relegated to their respective species, and that the evidence was trustworthy, was later proved when in material in the collection of the Helminthology Department, taken from the above host, *one* of the species in question was found, and in both sexes the cephalic vesicle had the same characteristic shape already observed. To this species, found on two occasions in *Lagothrix humboldtii*, the name *E. lagothricis* is given, and the name *E. duplicidens*, by virtue of the cleft teeth in the female, is given to the other.

During the process of separating the females of these species into two lots, which necessitated the examination of the head region of each worm under a high magnification, two immature females of a third Oxyurid species were found. The three teeth in the vestibule suggest affinities with the family Subuluridæ, but the data are insufficient for a definite diagnosis to be attempted.

The writer wishes to express his thanks to Professor R. T. Leiper for access to the material here described and for helpful advice regarding it.

DESCRIPTION OF *E. lagothricis* sp. nov.

Female. The maximum length of gravid specimens in the first material obtained was about 5 mm., but in the second lot, which was in a better state of preservation, the maximum length was slightly over 6 mm., and the breadth about 3 mm.

The cephalic vesicle does not extend to the anterior extremity of the body, the head projecting about 10μ beyond it. It is composed of thick cuticle, and anteriorly it forms a slightly curved collar at an angle of about 45° to the body. Immediately behind the collar is a constriction, from which the vesicle keeps a uniform diameter until it meets the body posteriorly. It resembles very closely that in *Enterobius minutus* as figured by v. Thiel (1925) and also independently by Travassos (1925). The body cuticle is striated and there is a pair of lateral cuticular ridges.

The circumoral papillæ are in two lateral groups of three, of which the central papilla in each group differs from the others in its smaller size and in being surrounded by a thick cuticular rim. In end-on view the head is somewhat rectangular, and at its four corners are situated

the other papillæ. In lateral view the head is symmetrical, and in this differs markedly from *E. atelis*, in which the dorsal side of the head is more forward than the ventral, due to the large overhanging dorsal lip. In *E. lagothricis* there is even less evidence than in *E. atelis* of the three lips characteristic of the genus, and bilateral symmetry of the head and mouth seems to have become established. The mouth opening is bounded by two broad ledges dorsally and ventrally, which even in the end-on view of the head, are very difficult to see. There is a well-defined vestibule whose lateral diameter is greater than the dorso-ventral, and its depth is considerably less than that of *E. atelis*. The œsophageal teeth are strong cuticular structures of characteristic shape. Their opposed faces are indented and anteriorly they bear two small sharp projections. The antero-dorsal part of the œsophagus, opposed to the teeth, is heavily cuticularised.

The œsophagus averages about 0·73 mm. in length, and its shape is typically Oxyurid. The posterior bulb varies from 0·104 mm. to 0·112 mm. in breadth, and its length is similar. The anterior bulb is 0·08 mm. to 0·088 mm. in breadth, and the narrow part joining it to the mouth is 0·04 mm. in diameter. The nerve ring surrounds this anteriorly, its position dividing the œsophagus in the ratio of 1 : 4·3. About the level of the posterior bulb is the excretory pore.

The vulva is anterior to the middle of the body, and divides it· in the ratio of about 1 : 3·6. The genital organs are similar to these in *E. vermicularis* ; the ovejector is composed of two parts, a short muscular portion leading back from the vulva to a longer thin-walled sac, to which the two uteri join from opposite directions. The eggs are 38 to 40μ long by about 22μ broad, somewhat flattened on one side, and the shell is smooth. They differ markedly from those of *E. atelis*, which are longer, more pointed at each end, and have a pitted surface.

Male. The males measure up to 1·56 mm. in length by 0·08 mm. in breadth. The cephalic vesicle and papillæ are similar to those in the female, but the mouth opening is narrow and elongated laterally, and the bordering ledges appear to be absent. The head and vestibule are symmetrical, the latter being more or less circular in section. Two blunt sub-ventral teeth are present and a third dorsal tooth projects somewhat farther into the vestibule. The œsophagus is 0·35 mm.

long, and the posterior and anterior bulbs are respectively 0·06 mm.
and 0·04 mm. in breadth.   The posterior bulb is slightly longer than
broad.
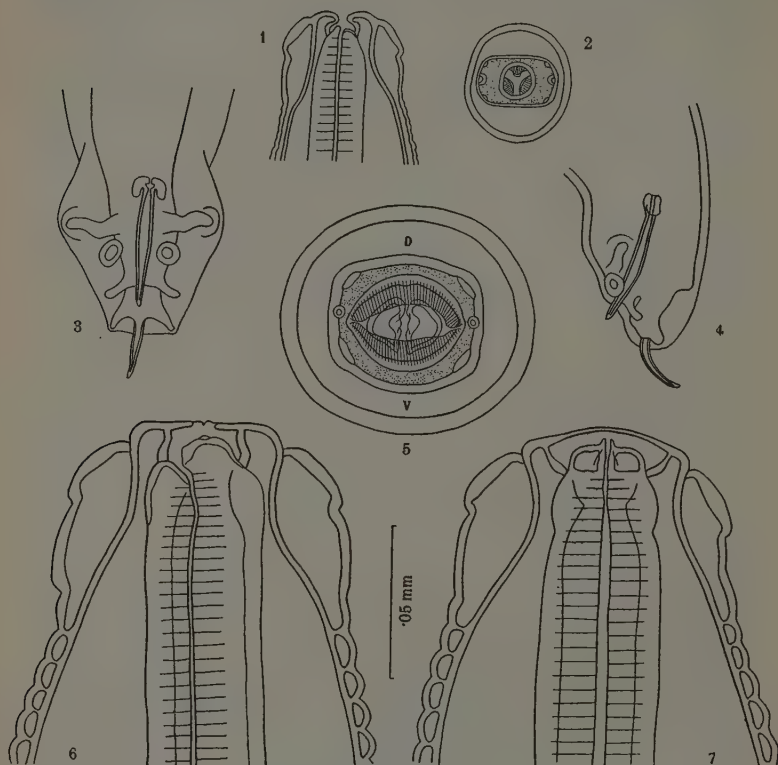
E. lagothricis.

1. Anterior end of male, lateral view.
2. Anterior end of male, end-on view, shewing papillæ, vestibule and teeth.
3. Tail of male, ventral view.
4. Tail of male, lateral view.
5. Anterior end of female, end-on view, shewing papillæ, ledges, vestibule and
   teeth.
6. Anterior end of female, lateral view.
7. Anterior end of female, dorso-ventral view.

The tail is curved ventrally, and bears four pairs of papillæ, the first and last pairs of which support a cuticular expansion. Of the middle pair, the anterior are short and thick, and the posterior are longer and thinner. Between these two pairs of papillæ is the anogenital aperture. Behind the latter pair is a deep transverse groove, directed anteriorly, and near the posterior end is a dorsal vesicle formed by retraction of the body away from the cuticle. A terminal spike about 0·015 mm. long arises from between the last pair of papillæ. The spicule is 0·44 mm. long, tubular, and its cavity is open at the anterior end, from which arise two lateral processes directed backwards.

DESCRIPTION OF *E. duplicidens* sp. nov.

Female. The longest gravid specimens seen were 4·6 mm. and the average breadth was about 0·3 mm. The cephalic vesicle reaches to within about 0·01 mm. of the end of the body. It is somewhat hemispherical, and posteriorly its cuticle gradually approaches the widening body wall, being kept distant from it by septa which correspond to the transverse striations on its surface. A pair of narrow lateral cuticular ridges are present and the transverse striations are distinct.

The head and circumoral papillæ are identical with those in the previous species, but the ledges bordering the mouth opening are narrower. It is in the teeth however that the most marked difference between the two species is displayed. In lateral view they are seen to be larger and almost fill the vestibule, and in dorso-ventral view each tooth is seen to be subdivided by a deep groove.

The œsophagus is considerably longer than in *E. lagothricis*, averaging 0·9 mm. but its shape and the dimensions of the two bulbs are indistinguishable from it. It is surrounded anteriorly by the nerve ring which divides it in the ratio of $1 : 5 \cdot 5$, The excretory pore is at the level of the junction of the two bulbs, and the anus 0·8 mm. from the tip of the tail.

The vulva divides the body in the ratio of about $1 : 3 \cdot 5$ and the genital organs and eggs are similar to those of the previous species.

Male. The males measure up to 1·6 mm. in length by 0·08 mm. in breadth. The cephalic vesicle does not resemble that of the female to such an extent as is the case in *E. lagothricis*. It is formed mainly as a result of a deep constriction of the body wall near the anterior end,

from which the cuticle comes away. The papillæ, mouth opening and
vestibule are as described in the previous species but the teeth are
distinctly different. There are two sub-ventral teeth and one dorsal,
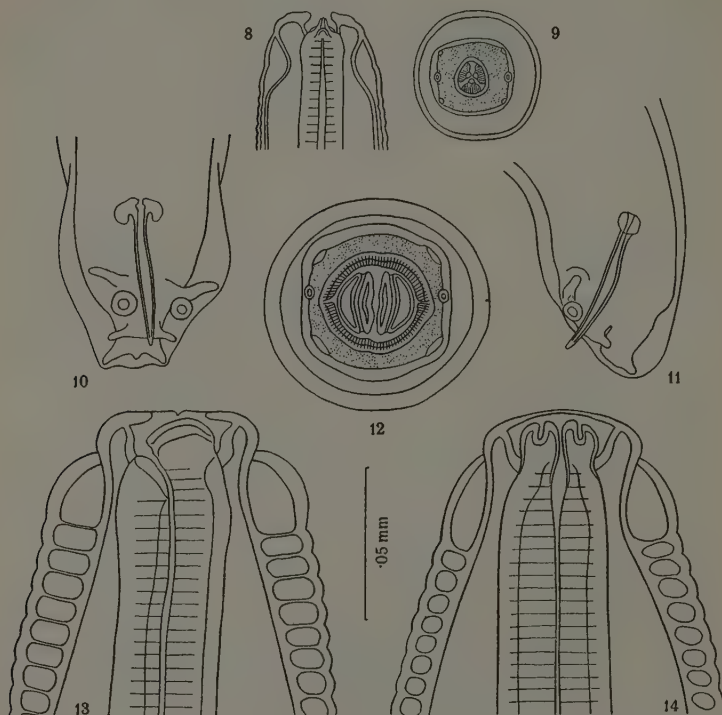
E. duplicidens.

8. Anterior end of male, dorso-ventral view.
9. Anterior end of male, end-on view, showing papillæ, vestibule and teeth.
10. Tail of male, ventral view.
11. Tail of male, lateral view.
12. Anterior end of female, end-on view, shewing papillæ, ledges, vestibule and
       teeth.
13. Anterior end of female, lateral view.
14. Anterior end of female, dorso-ventral view.

and the three are similar in size and structure.   They are slender and
taper to a sharp point, and each arises from a stout basal prominence.

The œsophagus averages about 0·38 mm. in length, with a posterior
bulb of 0·068 mm. long by 0·05 mm. broad, and an anterior bulb of
0·04 mm. broad.   The tail is similar to that of *E. lagothricis* except
that the terminal spike is absent and the spicule is longer, measuring
0·052 mm.

<center>IMMATURE OXYURIDS.</center>

The two specimens found were respectively 2·3 mm. and 3·4 mm.,
in length and about 0·15 mm. in breadth.   There is a cephalic vesicle

·05 mm
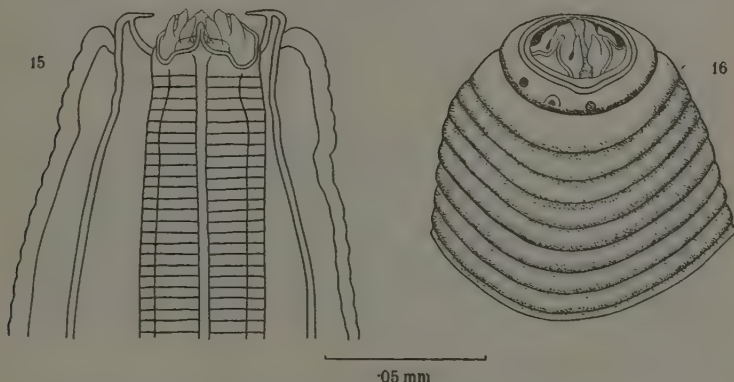
IMMATURE OXYURIDS.
15. Anterior end, semi-lateral view. (One sub-ventral tooth in centre.)
16. Anterior end, semi-terminal view.

as depicted in Fig. 15 and the head projects slightly beyond it.   Three
pairs of papillæ in two lateral groups of three each, are situated near
the mouth opening ; the central papilla of each group is incompletely
enclosed by a cuticular rim.   Lips are evidently absent, the mouth
opening being more or less circular.   There is a vestibule containing
three elaborate tricuspid teeth, each composed of a large stout central
tooth, and two smaller more delicate teeth.   The œsophagus is 0·76 mm.
long and is typically Oxyurid, consisting of a long narrow part 0·04 mm
in diameter, which terminates in a bulb 0·07 mm. in breadth.   A narrow
constriction separates this from a second bulb 0·1 mm. in breadth.

The vulva is anterior, dividing the body in the ratio of $1 : 2 \cdot 8$; the rest of the genital system was quite undeveloped. The tail is long and tapers to a sharp point, and measured $0 \cdot 44$ mm. and $0 \cdot 64$ mm. in length in the two specimens. The cuticular striations are about 5μ apart, and lateral longitudinal ridges are present.

Conclusion.

The occurrence of two new species of *Enterobius* in a monkey, recorded here, is of particular interest in as much as it is a striking exception to the rule which otherwise seems to hold good with reference to this genus, that each species of *Enterobius* is restricted to one genus of host. This rule was first observed by Cameron (1929) who remarked that owing to its peculiar life history, this genus tends to be a parasite of the individual, and in consequence each species is likely to be restricted to one kind of host.

The above exception is explicable on the supposition that the restriction is *only* one of habit, and that a physiological host-parasite relationship has not become established. Thus in the natural environment, one genus of monkey might be accidentally exposed to infection with a species of parasite associated with another genus of host, and the infection would take hold. Under artificial conditions, such as were present in the case under discussion, the opportunity for such an infection would be even more likely to occur.

Again, it might be argued that the species in question do not really belong to the genus *Enterobius*, and hence the rule is inapplicable to them ; for there appears to be ample justification, on the basis of structural differences, for the erection of a new genus for these two species, and *E. atelis*.

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On *Longistrongylus meyeri* gen. and sp. nov., a Trichostrongyle parasitizing the Red Hartebeest *Bubalis caama*.

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Introduction.

In June, 1930, the writer received from Mr. T. Meyer of Onderstepoort, some parasites collected from a red hartebeest at Gobabis in South West Africa. The examination of this material revealed the presence of rather long slender worms which could not be allocated to any of the known genera of the sub-family *Trichostrongylinæ*, Leiper, 1908. The genus *Longistrongylus* is proposed for the reception of this species which is named *Longistrongylus meyeri* gen. and sp. nov., in honour of the collector and donor.

Longistrongylus Gen. Nov.

Definition. *Trichostrongylinæ* : Head relatively large, lips inconspicuous, buccal cavity small ; cervical papillæ present, but small ; cuticle with very fine closely spaced transverse striations, prominent longitudinal ridges intersecting the transverse striations. *Male* : Copulatory bursa with large lateral lobes and a distinct, but much smaller symmetrical dorsal lobe with the following formula : Ventro-ventral and latero-ventral, arising from a short common trunk proximally, are long, parallel, equal in size and terminate close to the edge of the bursa ; externo-lateral stops short of the edge of the bursa and its distal extremity is well separated from the neighbouring rays ; medio-lateral and postero-lateral, about equal in dimensions, are long, parallel and arising from a short common trunk proximally end near the edge of the bursa ; externo-dorsal springs from the base of the dorsal ray and is short ; dorsal ray bifurcates almost

immediately into two short stout branches, each of which in turn terminates in two or three very short digits ; prebursal papillæ long and stout ; spicules equal, slender, alate and each ending in two short points ; telamon present. *Female* : Uteri divergent and opposed ; vulva in the posterior fifth of the body and opening into a transverse depression ; tail rather bluntly pointed ; oviparous.

Type species : *Longistrongylus meyeri* sp. nov.

	Females.			Males.	
Length of body	24·5	25·2	27·3	14·4	15·8
Diameter of head	0·062	0·063	0·065	0·036	0·037
Maximum breadth of body ...	0·384	0·437	0·375	0·247	0·263
Breadth of body at base of œsophagus	0·214	0·212	0·207	0·247	0·240
Anterior extremity to nerve ring ...	0·436	0·425	0·463	0·336	0·357
Anterior extremity to excretory pore	0·684	0·653	0·764	0·454	0·516
Anterior extremity to cervical papillæ	0·735	0·674	0·727	0·486	0·547
Anterior extremity to vulva ...	19·374	21·362	21·473	—	—
Length of œsophagus	1·362	1·652	1·463	1·218	1·212
Maximum width of œsophagus ...	0·144	0·126	0·138	0·097	0·095
Minimum width of œsophagus ...	0·036	0·047	0·043	0·027	0·032
Anus to posterior extremity ...	0·245	0·243	0·252	—	—
Length of rectum	0·133	0·133	0·133	—	—
Measurements of the eggs { Length	0·075	0·077	0·077	—	—
in utero { Breadth	0·045	0·045	0·045	—	—
Length of spicules	—	—	—	0·300	0·312
Dorsal lobe of copulatory { Length	—	—	—	0·048	0·053
bursa { Breadth	—	—	—	0·108	0·113
Lateral lobes of copu- { Length	—	—	—	0·288	0·315
latory bursa { Breadth	—	—	—	0·300	0·327

MORPHOLOGY OF *Longistrongylus meyeri*.

The different measurements of the three females and the two males are shewn in the subjoined table.

The worms are rather long and thin. They are fairly straight, although primarily preserved in 10 per cent. formalin and are dark red in colour. Live specimens were, according to the donor, deep dark red in colour at the time of collection. That the species is an active blood sucker would seem possible judging from the dark amorphous pigment present in the intestinal cells throughout the whole length of the intestine.

Anteriorly and posteriorly the female is attentuated. The attenuation is more gradual anteriorly.

The cephalic extremity bears ill-defined lips with the usual circum-oral papillæ inconspicuous. The oral aperture leads into a very small buccal cavity, followed by the type of œsophagus typical of the sub-family (fig. 1). The œsophageo-intestinal valves are not well developed. The rectum is of the usual type and the anus, in the female, oval in outline.
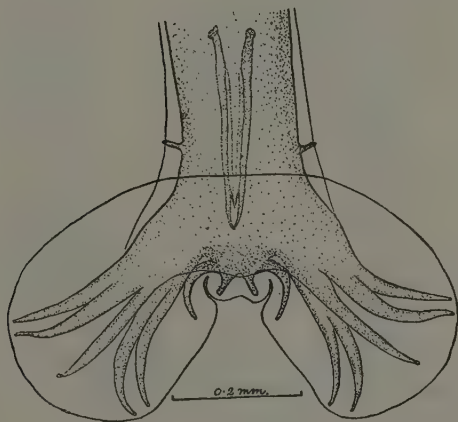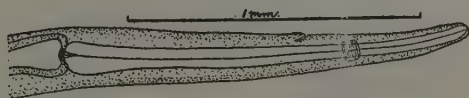
Longistrongylus meyeri n.g., n.sp.

Fig. 1.—Cephalic extremity.

Fig. 2.—Bursa spread out. Spicules showing.

The cervical papillæ are rather small nipple-like projections situated on a level slightly posterior to the excretory pore which in turn is posterior to the nerve ring.

The cuticle bears from forty to about fifty well-developed longitudinal lines towards the posterior part of the body. These lines extend from about the level of the nerve ring to the level of the anus in the case of the female and the prebursal papillæ in the male. They are more numerous posteriorly than anteriorly, and do not in every case extend uninterruptedly from in front to behind. The transverse striations are ill-defined and very closely spaced together. They are interrupted by the well-developed longitudinal ones.

The male. The males are less darkly coloured than the females and
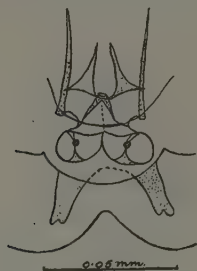
Longistrongylus meyeri.

Fig. 3.—Telamon as far as could be made out. Branches of dorsal ray showing.

appear much more slender. They attain their maximum breadth about the junction of the middle and posterior thirds. The testis is prominent and extends anteriorly to within a short distance of the base of the œsophagus. The spicules are similar in shape and size, but rather small and slender. Each spicule bears a spur ventrally towards its distal extremity which ends in a sharp slightly curved point. The spur is the termination of the transversely striated ala with which each spicule is furnished (fig. 2). The copulatory bursa is comparatively underdeveloped for a worm of this size. The lateral lobes are supported by rays as figured (fig. 2).

The spicules are guided by a telamon. The exact build of this structure could not be accurately ascertained (fig. 3). The cloacal aperture is

furnished ventro-laterally with two papillæ around which the cuticle is inflated to form spherical swellings (the genital cone).   These two papillæ have been observed in *Hæmonchus contortus*, *Trichostrongylus axei*, *T. instabilis*, *T. rugatus* and *T. falculatus*.

The Female.   Microscopically these parasites may, on account of the twisting of the genitalia around the reddish coloured intestine, be mistaken for specimens of *Hæmonchus* Cobb, 1898 ; *Ashworthius* le Roux, 1930 ; or even other members of this large sub-family.
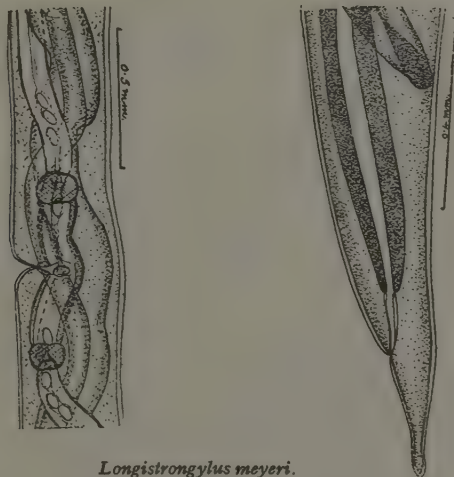
Longistrongylus meyeri.

Fig. 4.—Body of female in region of vulva.
Fig. 5.—Caudal extremity of female.

The vulva is situated in a transverse depression on the ventral aspect of the parasite.   The vagina is very short.   The ovejectors (fig. 4) are muscular.   The eggs *in utero* measure from 75μ to 77μ in length and attain a breadth of from 45μ to 48μ, and show segmentation.   This segmentation may, however, have taken place after the collection and the preservation in formalin.   The caudal extremity is attenuated and ends in a rather blunt point.   The caudal papillæ are present.

Co-types of this species will be deposited in the Helminthological collection at Onderstepoort and in the collection of the Imperial Bureau of Agricultural Parasitology, St. Albans, as well as with the Department of Zoology, University of Edinburgh.

On some Lungworms of the Malay Tiger.

By Thomas W. M. Cameron, M.A., D.Sc., M.R.C.V.S.

(*Lecturer in Helminthology in the University of Edinburgh.*)

At the beginning of this year, a Malay Tiger (*Felis tigris*) which had been nearly two years in the Edinburgh Zoological Gardens, died. On post mortem examination, it was found to harbour *Dibothriocephalus felis, Galoncus perniciosus* and *Toxascaris leonina* in its small intestine ; and *Paragonimus westermani, Capillaria* sp. (a single female) and the three nematodes which are the subject of this paper, in its lungs.

Syngamus felis sp. nov.

Nine pairs of Syngamus were recovered from the bronchi. They were bright red when alive, becoming brown when fixed.

The average length of the male is 6·25 mm. (5·5 mm. to 7·0 mm.) and of the female, 23 mm. (17·5 mm. to 26·5 mm.). The ventral surface of the male is directed away from the female.

Male. The body of the male is uniformly cylindrical from the terminal buccal capsule to the bursa. The buccal capsule is spherical with a diameter of one millimeter and with relatively thick walls. There is a group of eight to nine teeth at the base of the capsule, but without internal ridges on its walls. The œsophagus is 1·2 mm. long with a maximum width of 0·3 mm. The bursa has a small dorsal lobe and a deep ventral notch. All rays are blunt and irregular, although a typical arrangement is found. The dorsal ray is Y-shaped with distinct externo-dorsal rays. The lateral rays are blunt, parallel and separate from each other. The ventral rays are blunt and close together, being joined at their base. It was only after a male had been dissected and

examined under the oil-immersion objective that the spicules were found. They are 25μ to 30μ in length, colourless and simple in structure, with relatively voluminous sheaths. There is a definite thickening of the cuticle within the bursa, surrounding the ano-genital opening, but there is no trace of an accessory piece.

Female. The body of the female tapers gradually and gently from about the middle of the body to the anus ; thereafter it narrows suddenly to form a distinct spine. Small caudal papillæ are present. The buccal capsule is wider than deep, its width being $1\cdot3$ mm. and its depth $1\cdot1$ mm. The walls are somewhat thinner than in the male. In both sexes the terminal mouth opening is spherical and surrounded by a cuticular ring ; the usual six papillæ are only faintly seen and do not project beyond the base of this ring. In the female, six of the teeth are provided with ridges on the inner surface of the capsule. The œsophagus is $1\cdot73$ mm. long with a maximum width of $0\cdot5$ mm.

The vulva is situated about 6 mm. from the anterior end of the body, so that the pre-vulvar part of the female and the male are approximately the same length. The uterine coils extend only a short distance posterior to the middle of the body.

DISCUSSION.

Four species of Syngamus have been recorded from mammals : *S. kingi* from man, *S. dispar* from the puma, *S. laryngeus* from ruminants, and *S. hippopotami* from the hippopotamus. (*S. nasicola* appears to be almost certainly a synonym of *S. laryngeus*.)

S. kingi has the uterine coils reaching to just in front of the anus ; the female does not taper posteriorly and her tail is sharply truncated. The parasite was found in St. Lucia in the West Indies in man, but the normal host is still unknown. *S. laryngeus* does not appear to be present on the island and in any case it seems to be quite distinct from this species. It resembles *S. dispar*, however, and although there are no wild carnivores present, dogs and cats are found.

S. dispar appears to be similar to *S. kingi*, but no modern account of its morphology is available. It was reported from *Felis concolor* from Brazil.

S. laryngeus which occurs in ruminants in various parts of the world,
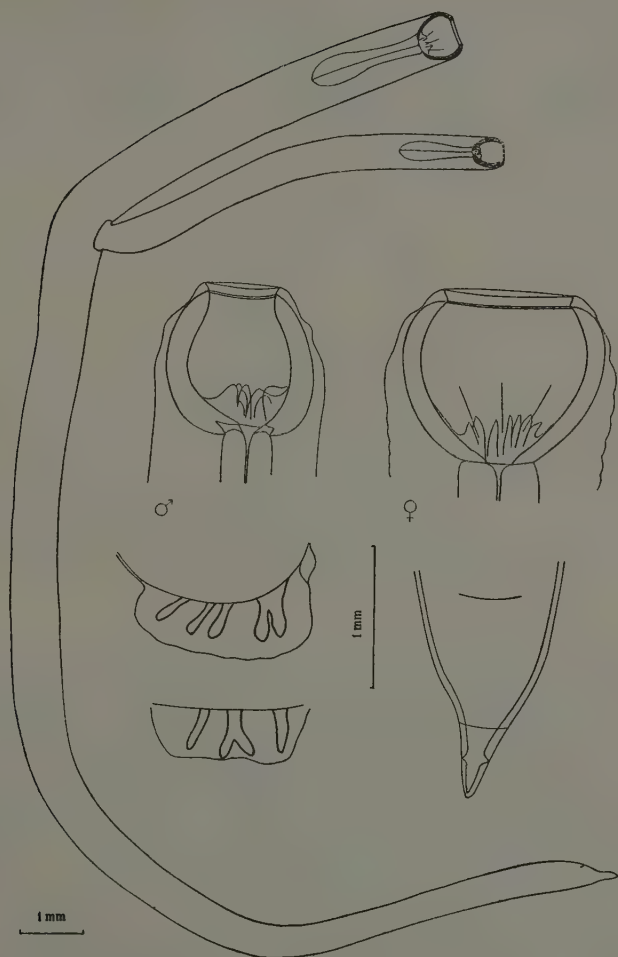
Syngamus felis n.sp., from a Malayan Tiger.

is smaller than the present species, the male being 2·6 mm. to 5 mm. and the female up to 20 mm. long. The females are definitely tapered posteriorly and the uterine coils terminate just behind the middle of the body ; the tail is subacute. The spicules in the male are about 25μ long and the lateral rays originate from a common stem.

S. hippopotami from the hippopotamus from the Belgian Congo has also a tapering body in the female. The male is 5 mm. to 8 mm. and the female 24 mm. to 34 mm. long. The buccal capsule in the male is as wide as, but shallower than that in the female. The dorsal ray is bifurcated to its base and the medio-lateral and postero-lateral rays are close together ; the spicules are unequal in size measuring 12 to 18μ and 18 to 24μ respectively. The tail of the female is short and conical.

These two last species appear to be somewhat closely related to the forms from the Malay Tiger. It is larger than the species found in ruminants however and differs in several morphological details from it as well as from that found in the hippopotamus. The host is widely different also ; and the fact that a number of worms were found in the animal after about two years in captivity in this country, suggests that it is not an abnormal parasite of the tiger. Accordingly these differences seem to justify the creation of a new species and the name *S. felis* sp. nov. is proposed for it.

" Hæmostrongylus " subcrenatus.

This species was described by Railliet and Henry in 1903 from the bronchi of a leopard (*Felis pardus*) from the Congo. It was found in the same position in the Malay Tiger. There is little to add to the original excellent description of this species ; and my specimens, which were white in colour when alive, agree in all respects with Railliet and Henry's account. It is difficult to understand, however, why this species was originally referred to the genus " Hæmostrongylus " as it differs in practically every important feature from the type of that genus.

The head has a swollen cuticular enlargement with a conspicuous ventral groove. The male has a broad single dorsal ray which bifurcates only at the tip ; the spicules are 780μ to 950μ long. The female has a conical tail ; the vulva is situated about the middle of the body, and the eggs are embryonated when laid. It lives in the bronchi.

Angiostrongylus vasorum, the type of " Hæmostrongylus " on the other hand has a simple head end without a cuticular enlargement. The male has widely separated dorsal rays and the spicules are only half the size. The female has a rounded tail ; the vulva is just in front of the anus and the eggs are not embryonated when laid. Moreover it lives in the blood-vessels and causes a verminous pneumonia by the arrest of the eggs in the finer capillaries of the lungs. The other species when
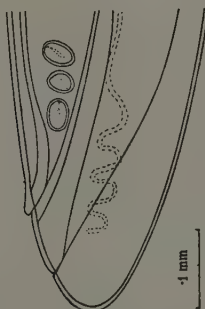
Oslerius sp. inq., female tail.

present in large numbers would presumably cause a bronchitis. These differences seem so striking that it seems to be justifiable to remove it from the genus Angiostrongylus (or " Hæmostrongylus ") to the new genus *Bronchostrongylus*, of which *B. subcrenatus* (Railliet and Henry) forms the type and only species.

There was present in the bronchi of the tiger in addition, several females of another species of nematode. It measures about 16 mm. to 18 mm. in length. The head is without any cuticular expansion. The excretory opening is at the junction of the anterior and second quarters of the œsophagus. The tail is blunt and conical. The vulva opens close to the anus and the genitalia is double. The most conspicuous feature is the prominent excretory vessels which are easily seen running an undulating course from one end to the other. The eggs, which measure 40μ by 30μ, have a thick shell and are embryonated in the uteri.

In the absence of males, it is impossible to make a definite identification of this species. The available descriptions of the female of *Oslerus osleri* and the habitat of that species in the bronchi of a carnivore, seem to agree with this, but that description is inadequate by modern standards and no specimens are available for comparison. On the other hand, it resembles the females of *Angiostrongylus vasorum*, but it lives in the bronchi and the eggs are thick shelled and embryonated. It is accordingly tentatively referred to the former genus until more abundant material is available for study.

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On a Species of Trichostrongyle from the Tasmanian Devil.

By Thomas W. M. Cameron, M.A., D.Sc., M.R.C.V.S.

(Lecturer in Helminthology in the University of Edinburgh.)

In a Tasmanian Devil (*Sarcophilus harisii*) which died last year in the Scottish Zoological Park, there were found examples of *Oochoristica dasyuri*, *Alaria* sp., and the following species of Trichostrongyle worm which appears to be new to science.

The worms were red in colour when alive and tightly coiled into a cylindrical spiral about a millimeter in length. When unrolled, a procedure which can only be accomplished with difficulty, the female measures about 5·25 mm., and the male about 3·45 mm. in length. The width in both sexes is about 0·12 mm.

The head is surrounded by a cuticular expansion which is more voluminous on the dorsal than on the ventral side. This expansion is terminated by a distinct constriction which entirely surrounds the body, and like the body is transversely striated. The terminal part of the œsophagus, which is 0·32 mm. long, is surrounded by a distinct buccal cavity with thickened walls and carries a large, triangular, dorsal tooth. There are no ventral teeth present. The excretory pore opens about the level of the middle of the œsophagus, on the concave side of the body.

The female genitalia is double and the genital tubes are only slightly convoluted. The vulva opens towards the posterior part of the body, which it divides in the ratio of 7 : 1. There is a small anteriorly directed

vagina and opposed ovejectors, each being about 0·2 mm. in length. The anus is situated about 0·1 mm. from the tip of the tail. The tail is conical in shape but contracts suddenly just before its tip, to form a distinct spine.

The eggs in the ovejectors are of the typical trichostrongyle type and measure 70μ long by 40μ broad.

The male bursa is very elastic, with a serrated margin. It is radially striated with bosses in the central area. When spread out it is seen

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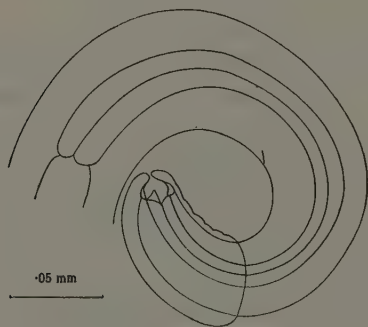
Nicollina sarcophili, anterior end.

to be symmetrical with a small dorsal lobe. The tips of the ventral and lateral rays are about equally spaced round the edge of the bursa but the externo-lateral ray, which is rather thicker than the other four, does not quite reach the edge of the bursa. This ray and the ventral rays are directed ventrally ; the others are directed dorsally. The externo-dorsal rays are long, slender and almost straight, lying close to the posterio-lateral rays. The dorsal ray is also a slender ray, bifurcating towards its distal quarter, with each bifurcation ending in two slender digitations. The two spicules are equal and similar. They are relatively long, slender, simple tubes with blunt rounded points ; they measure 0·4 mm. The accessory piece is also simple and flat, measuring 85μ in length.

This species is obviously closely related to *Nicollina tachyglossi* Baylis and *N. echidnæ* Baylis, from *Tachyglossus aculeatus*. It differs from both of these however in a number of details. There are no longitudinal crests to the body, which retains its coiled state when fixed. The dorsal
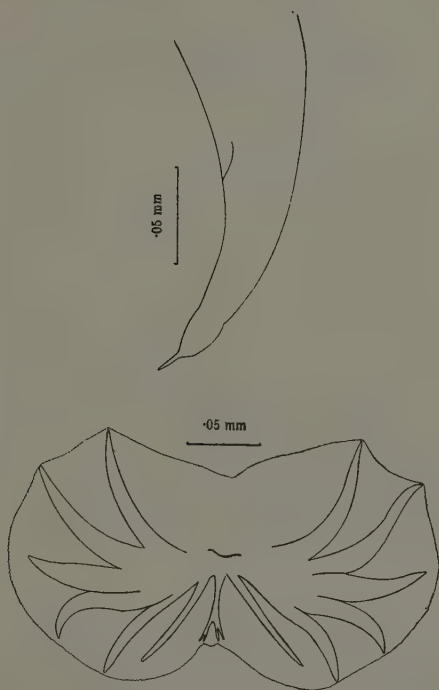
Nicollina sarcophili, female tail and male bursa.

ray has a small dorsal lobe and its terminal digitations differ. In the female, the tail terminates in a simple spine. In general, it appears to be more closely related to Austrostrongylus than are either of Baylis's species. Its differences from that genus appear to be greater than its differences from *Nicollina* and accordingly it is referred to that genus with the specific name of *N. sarcophili* sp. nov.

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Further Observations on *Tylenchinema oscinellæ* Goodey, 1930, a Nematode Parasite of the Frit-fly.

By T. GOODEY, D.Sc.

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INTRODUCTION.

IN the original paper dealing with this interesting nematode a fairly complete account was given of its discovery, its life-history in the free-living condition and within the host. In addition, its effect on the host, whereby flies of both sexes are sterilised owing to its presence, was also described. Its occurrence in both the stem and panicle generations of frit-flies attacking oats was recorded and figures were presented showing the incidence of infection in flies of these two generations. At the same time the inference was drawn that the parasite must also occur in the over-wintering generation of the frit-fly, larvæ of which attack wild grasses or winter cereals. Observations were therefore necessary on flies of this generation emerging during 1930 to prove conclusively the presence of the parasite. These observations are dealt with in the present paper and figures are given showing the degree of infestation in both male and female flies.

One point of importance in the biology of the larvæ of the parasite within the body-cavity of the host was not elucidated in the original paper, namely the site of entry into the gut of the host of those larvæ making their way to the exterior. This has been cleared up by observations carried out during 1930. Additional observations have been made on the effect of the parasite on the host, particularly on the genitalia of male frit-flies and conversely, on the effect of the host on the parasite. Larvæ passed from the anus have been investigated and observations made on the time occupied in passing through the two final moults in the free-living condition and the duration of life of these young adult worms.

More than 10,000 flies of the three generations, over-wintering, stem and panicle, were collected and dissected during the year and careful

records kept of the incidence of infection with *Tylenchinema*, of its distribution between the two sexes of the host and of the number of gravid female parasites per fly. Figures are given for these findings. Further records on the geographical distribution of the parasite and some remarks on its systematic relationships are also presented.

<div align="center">SITE OF ENTRY OF LARVÆ INTO GUT OF HOST.</div>

As described in the original memoir, one or more spermatized female Tylenchinemas make their way into the body-cavity of a frit-fly larva and remain there throughout its subsequent metamorphoses until when the fly finally emerges from the pupal case, the worm has grown enormously in size and is usually coiled amongst the viscera within the abdomen. Here it becomes viviparous and passes large numbers of larvæ into the body-cavity of the host. When these have grown to about 0·5 mm. in length and the gonads in both sexes have developed considerably, they make their way into the gut of the fly and pass to the exterior via the anus. The exact port of entry into the gut was not determined during the investigations carried out in 1929, but it was suggested in the original paper (p. 324) that it was probably " between the cells of the wall of the stomach, since both fore- and hind-intestine are lined throughout with a thin layer of chitin." This has proved to be an incorrect surmise as observations carried out during 1930 have shown that the larvæ make their way through the wall of the food reservoir and from there pass on into the other regions of the gut.

The alimentary canal of a frit-fly, with the exception of those portions immediately connected with the mouth parts, is made up of the following sections (see fig. 1) ; being of a typically dipterous pattern as figured by Imms (1925, p. 100).

(1) *Fore-intestine.*—This consists of a narrow œsophagus lying in the hinder part of the head and the fore part of the thorax. The tube branches and leads, on the one side, into the proventriculus and on the other, into the long narrow duct of the food reservoir. The food reservoir itself lies in the broadest anterior region of the abdomen. It is very thin walled and is therefore ruptured extremely easily when these very small flies are dissected under the microscope. This organ and its duct are merely a dilatation of the œsophagus and like that are lined throughout with a
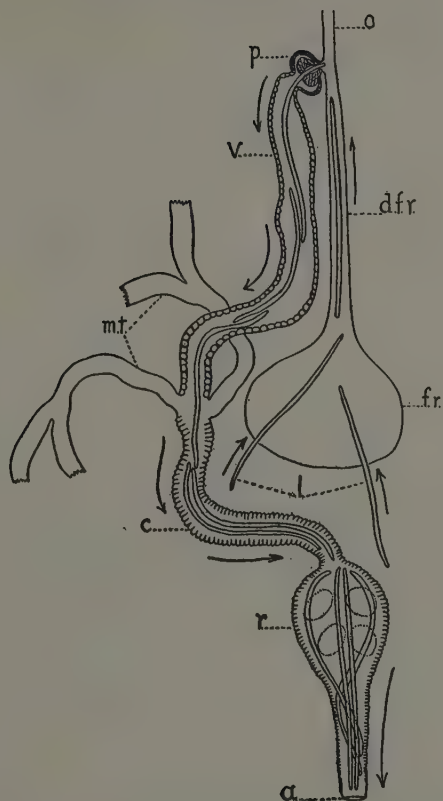
Fig. 1. Gut of frit-fly somewhat schematized, showing route taken by larvæ of *Tylenchinema oscinellæ* in passing to exterior : a., anus ; c., colon ; d.f.r., duct of food reservoir ; f.r., food reservoir ; l., larvæ getting into food reservoir ; m.t., Malpighian tubes, beginnings of branches only shown ; o., œsophagus ; p., pro-ventriculus ; r., rectum ; v., ventriculus or stomach.

very thin intima of chitin. The proventriculus is small, rounded and somewhat pumpkin shaped. Its walls are rather thick and the anterior one is invaginated as a large muscular thickening, functioning as a valve, through which the lumen formed from the œsophagus and the duct of the food reservoir passes.

(2) *Mid-intestine.*—This is a long tube, much wider than the duct of the food reservoir, whose walls are made up of numerous epithelial cells easily visible under the microscope, as well as an inner layer of circular muscles and an outer layer of longitudinal muscles, all enveloped by a thin peritoneal membrane.

(3) *Hind-intestine.*—This consists of two parts, colon and rectum. At the junction of the former with the mid-intestine the two Malpighian tubes arise, one on either side and each after a short distance divides into two. The colon is tubular, a little shorter and narrower than the mid-intestine, whilst the rectum is pyriform in shape. The walls of both these regions contain inner longitudinal muscles and outer circular muscles which give the organs an annulate appearance when seen in surface view. In the wall of the rectum there are four oval inwardly projecting papillæ or " rectal glands." This region opens to the exterior by the anus.

In the vast majority of the frit-flies dissected soon after being chloroformed and found to be infected with *Tylenchinema*, the parent worm or worms have been observed free in the body-cavity where larvæ also have been found as well as within the intestine. In very many cases larvæ have been found tightly packed together in the colon and rectum and less frequently have they been seen in smaller numbers in the mid-intestine. Only on three occasions has the writer been fortunate enough to see larvæ actually making their way into the gut and each time they were boring into the wall of the food reservoir. The second of the observations is detailed here. On July 11th, 1930, a female fly was dissected in Ringer's solution and the entire gut from œsophagus to rectum was obtained complete without rupture. Larvæ were observed making their way through the wall of the food reservoir, one was in the duct from the reservoir, another was partly in the proventriculus and the mid-intestine, many were seen in the mid-intestine, the colon and the rectum ; in fact, larvæ were found throughout the entire gut. This preparation was fixed in hot 70 per cent. alcohol with glycerine, stained with Nile blue and afterwards was successfully mounted in weak glycerine with the result that

larvæ can be seen in all the sections of the gut mentioned. It is clear to the writer that the route taken by the larvæ from the body cavity of the host to the exterior is first through the wall of the food reservoir and not, as originally suggested, through the wall of the mid-intestine. It is true that the food reservoir has a very thin lining of chitin, but even so the wall is extremely delicate and can offer but little resistance to the penetrating movements of the larvæ. On the other hand, in order to get through the wall of the mid-intestine, the larvæ would have to bore through an outer peritoneal membrane, then two layers of muscle and finally through or between the cells of the enteric epithelium. It is clear, therefore, from the observations recorded above that the larvæ, in going through the wall of the food reservoir follow the route of least resistance.

Larvæ in Malpighian tubules.

On p. 324 of the original paper the writer says : " in no case have larvæ been found within the Malpighian tubules." During last season's observation, however, larvæ were seen in these organs on three separate occasions. Each time they were closely watched in order to determine the direction in which they were moving, *i.e.*, towards or away from the main tract of the gut. In all three cases the movement was away from the gut and the larvæ were seen actively pressing against the closed end of the tubule containing them as though attempting to force their way out. The impression formed by the writer in each case, in watching the movements of the larvæ was that, in passing from the stomach to the colon, they had wandered into a tubule by mistake. The direction of their movements in pressing into the distal end of the tubes away from the lumen of the gut is directly opposed to the tubes being used as ports of entry into the gut.

PARASITISM.

(1) *Effect on Host.*—In dealing with this in the original paper it was shown that the presence of the parasite leads to the sterilisation of both male and female frit-flies by checking the normal development of the gonads. In the female the ovarioles making up each ovary are occupied by very small undifferentiated cells, whilst in the male each testis remains small and rudimentary, with no proper growth of spermatocytes and spermatozoa from the original germarium cells. It was also stated that in the case of the male, the rudimentary

condition of the testes is "accompanied by complete suppression of the accessory glands." The words quoted are somewhat of of an overstatement since greatly reduced, delicate rudiments of accessory glands have been discovered in parasitized male flies dissected during the past season. They are difficult to make out, however, even in those cases where after careful dissection it has been possible to disentangle the reproductive organs from the surrounding viscera and fine tracheoles ramifying these regions. It is clear, however, that they are not entirely suppressed, as was at first thought.

The matter is not of great importance, except as a point of detailed observation and accuracy, and in no way affects the general conclusion that the parasite brings about the sterilisation of the host by preventing the normal growth of the gonads.

(2) *Effect on Parasite.*—The normal course of events is for the parasite to sterilise the host, but, as was pointed out on p. 333 of the original paper, a few cases of infection of both male and female flies were observed in which the gonads of the host were normal in size, and apparently in function, whilst the parasite was small and degenerate with an incompletely developed ovary. These findings are supported by the observations carried out during 1930. However, whereas in 1929 none of the small undersized examples of *Tylenchinema* were found to have produced larvæ, one specimen was found during last summer's observations which had shed a few larvæ into the body-cavity of the host. On June 30th, an infected male fly was found with normal testes and accessory glands containing one small *Tylenchinema* which had developed so far as to have been able to produce five larvæ. These were all very small ; three were free in the body-cavity of the fly and two were seen in the rudimentary uterus of the worm. It was clear, however, that in this case, even though a few larvæ had been produced, these were destined to remain undeveloped and that the host had established complete ascendancy over the parasite.

Out of a total of 610 flies found to be infected during the course of the dissections of flies taken at Winches Farm during 1930, only 17 were found to have normal gonads and small degenerate parasites, whilst only one of the latter had succeeded in producing a few larvæ ; in the other 16 the ovary had remained small and degenerate. The distribution of these 17 degenerate parasites amongst the three generations of frit-flies

is set out in the accompanying table :—

Date.	Sex of fly.	No. of parasites per fly.	Remarks.	Generation.
4. vi. 30	Male	1	Testes, acc. glds., normal ...	Over-wint.
30 vi. ,,	,,	1	Testes, acc. glds., normal, 5 very small larvæ	Stem
4. vii. ,,	,,	1	Testes, small, acc. glds., large...	,,
8. vii. ,,	,,	1	Testes, acc. glds., normal ...	,,
19. viii. ,,	,,	2	,, ,, ,, ...	Panicle
,, ,,	,,	3	,, ,, ,, ...	,,
20. viii. ,,	Female	2	Ovaries, normal	,,
,, ,,	Male	1	Testes acc. glds. normal ...	,,
,, ,,	,,	2	Testes, rather small, acc. glds., large	,,
21. viii. 30	,,	1	Testes, acc. glds., normal ...	,,
22 ,, ,,	,,	1	,, ,, ,, ...	,,
,, ,, ,,	,,	1	,, ,, ,, ...	,,
,, ,, ,,	,,	2	,, ,, ,, ...	,,
23 ,, ,,	Female	1	Ovaries, normal	,,
,, ,, ,,	Male	1	Testes, acc. glds., normal ...	,,
,, ,, ,,	,,	1	,, ,, ,, ...	,,
,, ,, ,,	,,	2	,, ,, ,, ...	,,

The following data show their relation to the total number of flies dissected belonging to each generation and to the numbers of flies found to be infected with *Tylenchinema*. Flies of the panicle generation thus

Generation.	No. dissected	Infected.	Degen. forms.	Normal.	Ratio, Deg./Nor.
Over-wint.	1,740	76	1	75	1/75
Stem	3,534	381	3	378	1/126
Panicle	4,338	153	13	140	1/10·77

show much the highest proportion of degenerate to normal parasites in infected flies. It is difficult to advance a reason for this since we have not a sufficiently intimate knowledge of the processes going on within the body-cavity of the fly larva and pupa as a result of which either parasite or host gains the ascendancy before the fly emerges.

Again, it is far from apparent why flies of this generation attain a higher degree of resistance to the sterilising action of the parasite than in the other two. Possibly it is connected in some way with the fact that the whole life-history of the host is passed through more rapidly in this than

in the other two generations (vide fig. 2). The tables bring out the fact that of the 17 flies with degenerate parasites only two are females, whilst 15 are males. One may perhaps infer from this, at any rate provisionally, that the male fly has a greater power than the female of withstanding the sterilising effect of the parasite.

BIOLOGY OF FREE-LIVING LARVÆ.

The earliest observations on the parasite clearly showed that the larvæ undergo two final ecdyses in the free-living condition, since they were found surrounded by two sloughed cuticles within oat stems containing frit-fly larvæ. It was a matter of interest, therefore, to make some observations on those larvæ ready to lead a life outside the host, i.e., those from within the gut of the fly. For this purpose the gut was dissected out from three parasitized flies, each having numerous larvæ in the rectum, on two separate occasions. The gut was placed in a drop of tap water in a shallow glass capsule and the rectum was broken open with needles when the larvæ swam out readily into the water. The capsule was then placed in a Petri dish having a shallow layer of water at the bottom in order to provide a moist atmosphere, the lid was placed on the dish and the latter put into an incubator at 18° C.

On examining after 17 hours many of the larvæ were seen to be undergoing the third ecdysis, whilst after 41 hours there were many completely developed males in one case, and in another case there were many larvæ within two cuticles, i.e., they were undergoing the final ecdysis. In many of these the buccal stylet, only found in the female worms, could also be seen after 41 hours. These necessary internal changes, required for the emergence of young adult males and females, are therefore rapidly passed through by those larvæ escaping from the anus, at any rate under laboratory conditions, and there is no reason to suspect that similar changes would not as speedily take place under natural conditions on the oat plant.

Observations were made from time to time on the worms in the capsules, and although numbers of males and females were present together in the same drop of water the females did not become spermatized, but remained with the uterus empty, thus incidentally proving that copulation is necessary and that the female is not a protandrous hermaphrodite. The males remained alive in the water for about a fortnight, whilst the females were found in active movement in one capsule 29 days after being removed
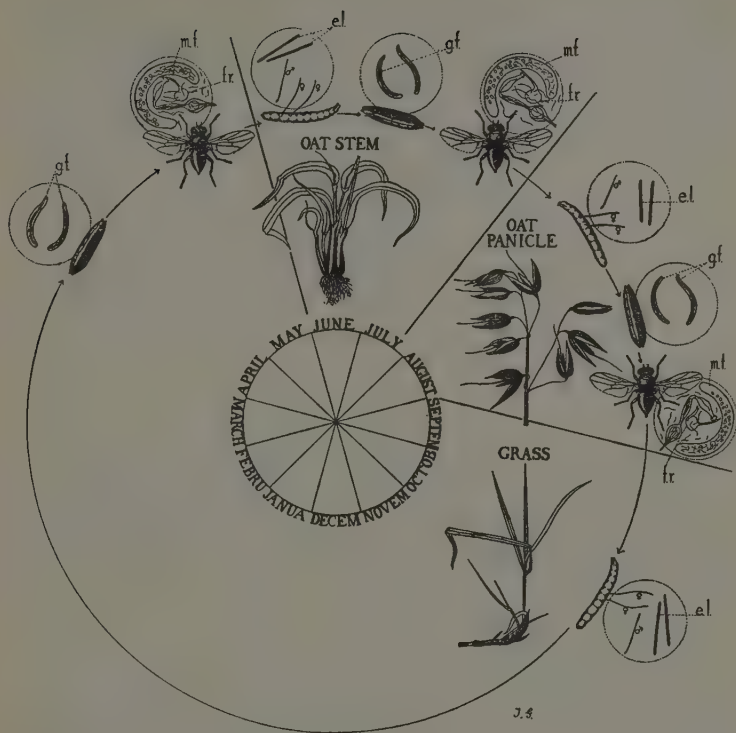
Fig. 2. Schematic drawing illustrating life-history of frit-fly in its three seasonal generations, and the approximate time occupied by each, linked with that of its parasite, *Tylenchinema oscinellæ*. The various stages of the fly and worm are greatly enlarged whilst the oats and grass are smaller than natural size. Although the female fly only is shown it is to be understood that the male also carries the parasite. The dotted circles contain stages of the parasite related to the corresponding stage of the host. The circles cut into the pupa and imago but not into the fly larva in each case, thus showing that the parasite is within the pupa and fly but not within the larvæ. e.l., ensheathed larvæ; f.r., food reservoir of fly with larvæ passing in; g.f., growing female worms; m.f., mature female worms.

from the rectum of the fly. It seemed probable that in the water of the capsule there was too much freedom of movement for the males to impregnate the females and that for copulation to take place a more restricted environment, such as occurs within the confines of an oat stem, was probably necessary. In order to test this, larvæ from the rectum of a fly were picked up by means of a capillary pipette in a small drop of water and transferred to a young oat plant in the following manner. The ensheathing leaf next to the central shoot was gently pulled aside and the point of the pipette pushed down between them. The larvæ were then expelled from the pipette and the leaf and shoot brought together again. After four days the whole shoot was dissected and from it a few *Tylenchinema* were collected, three of which were females with uterus crowded with spermatozoa, thus showing that copulation and impregnation had taken place under the confined conditions between the central shoot and the ensheathing leaf.

INCIDENCE OF INFECTION.

The plot of oats at Winches Farm from which frit-flies parasitized with *Tylenchinema* were first obtained in 1929 was sown again with oats at the end of February, 1930, with a view to the further investigation of the worms. As it was planned to pursue systematic sweepings of the oats, a word or two is necessary on the lay-out of the plot and of the method followed in collecting the flies.

The plot is approximately 1/10 acre in area, is 200 ft. long by 20 ft. 6 ins. wide. Oats were drilled lengthwise of the plot in rows about 1 ft. apart, and there were 19 rows in all. In order that the periodic collections of the flies should be comparable throughout it was decided that on each occasion a sweep should be made of three rows. Further, with a view to obtaining as representative a collection as possible, and at the same time avoid sweeping over the same rows time after time, the three rows selected were chosen as being one towards each side and one towards the middle of the plot. By sweeping three rows approximately in these regions the collections were in time made to cover the whole plot.

The collections were not limited to the original plot (H2e), but were also made from another one (H4a) on the same field and likewise 1/10 acre in area. This plot was sown in April in order to test whether later sowing gave a higher incidence of frit-fly attack than earlier sowing. There were

20 rows of oats on this plot, three of which were periodically swept in exactly the same way as those on plot H2e.

In order to obtain flies of the panicle generation, 200 oat stems, each showing a panicle, were taken by random sampling over the whole of each plot and were placed in suitable breeding boxes provided with closed tubes into which the flies came. These flies were collected daily, and after being chloroformed were dissected in Ringer's solution, following the method adopted in the preceding year's work and in the examination of the flies of the over-wintering and the stem generation.

Over-Wintering Generation.

On pp. 317-8 of the original paper it is explained that the flies of the panicle generation emerging in August and September lay eggs on various wild grasses and that the larvæ hatching from these continue to live in the grass stems throughout the winter months. Pupation takes place round about April, and the adult flies emerge during May and June in time to deposit eggs on spring-sown oats. Collection and examination of flies of this generation were therefore undertaken in order to determine the incidence of infection with *Tylenchinema*, and the accompanying figures give the totals of the dissections carried out from May 5th to June 20th, inclusive.

No. of flies.	Fem.	Male.	Inf.	Fem.	Male.
1,740	903	837	76	51	25

These figures show a slight preponderance of females over males in the collected flies and, amongst those found to be infected, twice as many females as males. The percentage infection for the whole period is 4·367, whilst the highest incidence was found on May 30th, when out of 192 flies collected, 15 were infected, which is 7·81 per cent.

Stem Generation (Plot H2e).

This plot was swept on alternate days from June 23rd to July 30th, except when it was too wet to make a collection. The following figures show the totals of flies collected, the number found infected and the numbers of each sex in both cases.

No. of flies.	Fem.	Male.	Inf.	Fem.	Male.
1,536	1,097	439	200	99	101

The percentage infection for the whole period is 13, whilst there were two collections which gave figures revealing an 18 per cent. infection. The plot was not swept systematically in 1929 and flies were only taken on two separate occasions when a 14 per cent. infection was obtained. It is therefore impossible to say whether there is a higher rate of infestation with *Tylenchinema* in 1930 than in 1929.

Stem Generation (Plot H 4a).

Figures for this plot are given below :—

No. of flies.	Fem.	Male.	Inf.	Fem.	Male.
1,998	1,445	553	181	95	86

As already explained, this plot was sown later with the idea of finding if it became more heavily attacked by frit-fly than that sown on February 28th. The total number of flies collected is certainly higher than from H2e, but against this must be set the fact that H4a was not swept for flies of the overwintering generation as H2e was and the smaller number of flies from the latter plot may be due to the fact that 900 females were collected from it which might have laid eggs and so have given rise to larger numbers of flies in the stem generation.

The percentage infection for the whole period is 9·06 and the highest individual infection was obtained on July 15th, when out of 189 flies collected, 23 were infected, which is 12·7 per cent.

The plot was swept on days alternating with the sweepings of plot H2e.

Panicle Generation (Plot H2e).

Flies from the 200 panicles placed in a breeding box were collected daily from August 7th to September 1st. The figures are given below :—

No. of flies.	Fem.	Male.	Inf.	Fem.	Male.
2,851	1,425	1,426	110	52	58

Panicle Generation (Plot H4a).

Daily collections were made of flies bred out from 200 panicles from August 12th to September 1st. The figures are given below :—

No. of flies.	Fem.	Male.	Inf.	Fem.	Male.
1,487	699	788	43	17	26

In the case of H2e the percentage infection for the whole period is 3·89 and the highest individual infection obtained was one of 10 per cent., whilst with H4a the corresponding figures are 2·89 and 5·3.

DISCUSSION.

The figures for flies of the stem generation from both plots show considerably more females than males, just as there were far more females than males amongst those flies taken in the two sweepings made from plot H2e in 1929. One might be inclined to infer from these figures that the male is more susceptible to infection than the female fly; in fact, the writer in his original paper says on p. 336: " There appears to be a significant difference in the incidence of infection between the sexes, both in this [panicle] and the stem generation, of flies collected at Winches Farm, the males in each case showing a higher degree of infection than the females."

The apparent preponderance of females over males revealed by the figures has, however, to be accounted for. The proportion of the sexes represented by the figures of flies collected by sweeping is, in fact, a false one. It is probable that the numbers of females and males are approximately equal in a really representative sample of the population for each generation. This is borne out by the numbers obtained in 1929 and 1930 of stem-generation flies supplied by Dr. A. D. Imms from Harpenden where they were bred out from a large number of pupæ collected from diseased oats. The figures for the two years are as follows :—

Year.				No. of flies.	Fem.	Male.
1929 ...	...	...	...	476	249	227
1930 ...	...	...	...	444	259	205

Figures of panicle-generation flies also show that there are about equal numbers of each sex as the following totals indicate.

Plot.		Year.	No. of flies.	Fem.	Male.
H2e	...	1929	3,472	1,926	1,546
,,	...	1930	2,851	1,425	1,426
H4a	...	,,	1,487	699	788

It is clear then that when the conditions are such that all the flies can be collected, the population is seen to be made up of males and females in approximately equal numbers. The much larger numbers of females than males in stem-generation flies swept in the open may be due to a difference

in habit between the sexes.   It should be made clear that during the month of July when the flies are active, the oat plant is growing rapidly taller and sweeping is carried out by running the net along the rows through the emerging panicles.   When at the same time it is realised that the damage done by the larvæ of this generation has been effected whilst the plants are still small, and that the pupæ are mainly found on the plants not far above soil level it will be evident that the flies on emerging are close to the soil.   It is possible, therefore, that the normal males, after pairing with the females, may remain closer to the ground than the females which must come up to lay their eggs on the panicles, and so, although emerging in about equal numbers to the females, such males escape capture by the net.

We can arrive at an estimate of the numbers of escaping males by the difference between the number of captured males and females ; thus in the stem generation of plot H2e the total of 1,536, made up of 1,097 females and 439 males, gives us by difference, 658 males escaping capture. This number, therefore, is required to bring the numbers of both sexes to parity.   If now we examine the figures for infected flies we find that there are practically the same number of males as females ; 99 of the latter and 101 of the former from which we may infer that the male is not more susceptible than the female, but that the parasite is about equally distributed between the two sexes.   The same process applied to the numbers from plot H4a gives us 892 males, escaping capture, required to bring the numbers of the two sexes to parity, whilst there is a practically equal distribution of the parasite between the sexes, 95 females to 86 males. The figures for the flies of the panicle generation from both plots show an almost even distribution of the parasite between the two sexes.

The assumption that a large number of males escape capture by the net (and it must be emphasised that it is a pure assumption that such males are normal) accounts for the large preponderance of females over males in collected stem-generation flies.   It does not throw any light, however, on why, amongst the males caught there is such a high incidence of infection with *Tylenchinema*.   It is possible that, owing to the sterilising action of the parasite the habits of the male are so profoundly affected that it no longer behaves in a manner normal to the male, but like a female goes upwards to the panicles where, instead of pairing, it deposits larvæ of *Tylenchinema*, and so assists in the further spread of the parasite.

NUMBER OF GRAVID FEMALE PARASITES PER FLY.

As a matter of interest a record was kept, as each fly was dissected, of the number of gravid female parasites in each infected fly. The totals for the three generations are given in the following table :—

Flies per host	1	2	3	4	5	6	7	8
Fem. frit-flies	243	53	11	5	2			
Male frit-flies	228	51	8	4	2	1	1	1

From these figures it is easily seen that one worm per fly is by far the commonest form of attack, whilst there is a rapid falling-off in numbers higher than two per fly. Further, only male flies showed infections of 6, 7 and 8 worms per fly. When it is borne in mind that one worm per fly is sufficient to bring about the sterilisation of the host, the above figures are of interest in providing us with some measure of the efficiency of the parasite as a sterilising agent. These worms were found in 610 flies, but by distributing the total number of worms at one per fly we find that 813 flies could have been parasitized if by some means the parasite could arrange so to infect its host that only one female worm entered a frit-fly larva.

GEOGRAPHICAL DISTRIBUTION.

In 1929 the parasite was found to have a wide distribution in England and Wales. During 1930 frit-flies were obtained from a few foreign countries and dissection of these showed that *Tylenchinema* occurs outside Britain.

The writer is greatly indebted to the following gentlemen for their kindness in supplying him with frit-flies from their countries :—Mr. P. Bovien, Statens Plantepatologiske Forsøg, Lyngby, Denmark ; Dr. H. Goffart, Biologische Reichsanstalt, Kitzeberg, Kiel, Germany ; Dr. I. N. Filipjev, Institute of Plant Protection, Bureau of Entomology and Applied Zoology, Leningrad, Russia ; Dr. B. Trouvelot, Ministry of Agriculture, France ; and Dr. J. M. Aldrich, U.S. National Museum, Washington, U.S.A.

Denmark.—The material consisted of two small tubes of flies which had been collected in July, 1913, and preserved since then in alcohol.

Tube.	No. Flies.	Fem.	Male.	Inf.	Male	Fem.	% Inf.
1	123	51	72	37	11	26	31·08
2	126	59	67	60	26	34	47·6

These figures reveal a remarkably high incidence of infection in both sexes, the highest in fact that the writer has encountered in any collection of frit-flies so far examined.   In the one tube practically one third and in the other about one half of the flies had been sterilised by the parasite which means that *Tylenchinema* was exercising a considerable measure of biological control over its host.   Unfortunately, owing to illness, Mr. Bovien was unable to collect frit-flies during July, 1930, so that it has not been possible to compare the infection obtaining at the present time with that of 1913.

Germany.—Two tubes of frit-flies were received, collected from an experimental plot of oats on July 12th, 1930.   They were preserved in alcohol and dissection revealed the following numbers.

Tube.	No. Flies.	Fem.	Male.	Inf.	Fem.	Male.	% Inf.
1	378	199	179	3	1	2	—
2	572	327	335	3	—	3	—
Total	950	436	514	6	1	5	0·73

The percentage infection is very low as compared with that of British flies and exceptionally low compared with the Danish results.

Russia.—Tubes of frit-flies were received which had all been collected during the month of August, 1930.   All were preserved in alcohol.   They were from seven different and widely separated districts, and in five of them *Tylenchinema* was present, as shown in the following results :—

(1) Shatilova Experimental Station, Central Black Soil area, 50 km. E. of Orel nr. Novosil.

(2) Siverskaya, N. Western Regional Expt. Station, 50 km. S.W. of Leningrad, between Leningrad and Luga.

(3) Vladimir Exptl. Field, Central Russia, 150 km. E. of Moscow.

(4) Simbiley Expt. Station.   Flies taken at Surovatich, Moscow-Kazan Railway, Nizhni-Novgorod Region.

(5) Durovo nr. Smolensk, Western Regional Expt. Station.

Place.

Place.	No. of flies.	Fem.	Male.	Inf.	Fem.	Male.
1	308	220	88	6	3	3
2	197	129	68	2	1	1
3	280	118	162	3	2	1
4	260	58	172	1	—	1
5	112	60	52	2	2	—

Only eight flies were received from France and 15 dried specimens from U.S.A., none of which harboured the parasite.

SYSTEMATICS.

On receiving a copy of the original memoir on *Tylenchinema*, Dr. Cobb favoured the writer with a reprint of a paper of his, privately printed by the Waverley Press, Baltimore, in 1928, and forming No. X. of his Contributions to a Science of Nematology. It contains a fuller account of *Howardula benigna* than that published in 1921. It is a matter for some regret that this paper was not at hand when the writer was compiling the section on the systematic relationships of the parasite in the original paper. There it was said (p. 337) that " *Howardula benigna* Cobb, 1921 . . . . has not been described in sufficient detail to enable one to make a close comparison with *Tylenchinema*. Cobb says that the male is unknown and that the female is syngonic, i.e., produces both sperms and ova." The view was also expressed that " males will be found to occur in *Howardula*, especially as Cobb says the young forms which enter the larvæ of the host are " already spermatised individuals."

It now appears from Cobb's later paper that males of *Howardula* had already been found at least two years before the words quoted were written. Moreover, the young adults of *Howardula* show certain points of resemblance to and difference from those of *Tylenchinema*, sufficient to warrant some further remarks on the matter.

Males.—(1) The stylet is vestigial in *Howardula* as in *Tylenchinema*. (2) The œsophagus in both appears to be degenerate. (3) The spicules in *Howardula* are straight and bluntly pointed, whereas in *Tylenchinema* they are curved and sharply pointed. (4) It would appear that very narrow lateral caudal alæ are present in *Howardula*, though not so well formed and definite as in *Tylenchinema*, where they are well developed.

Females.—(1) A stylet is present in *Howardula* as in *Tylenchinema* and appears to have practically the same shape in both being conical anteriorly, the shaft cylindrical and without basal thickenings. (2) The principal difference between the two genera is in the glands and their openings into the lumen of the œsophagus. In *Tylenchinema* there is a single, large, uninucleate *intestinal* gland which extends about half way down the dorsal side of the intestine and opens into the lumen of the œsophagus by a clearly defined duct entering it at right angles about 0·03 mm. posterior to the end of the stylet.

In *Howardula*, Cobb says, there are three *œsophageal* glands the dorsal one of which opens by a duct and an ampulla near the base of the spear, whilst the two large coarser glands empty a little farther back. These differences are such that the writer does not feel justified in proposing any alteration in the generic status of *Tylenchinema*. At the same time it is clear that as our knowledge of the structure of these interesting parasites of insects becomes more extensive it may be necessary to propose certain alterations in their systematic relationships.

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On the Eelworm *Heterodera schachtii* attacking Peas in Britain.

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In June, 1931, some specimens of field-grown peas infested by eelworms were sent for diagnosis to the Institute of Agricultural Parasitology by Mr. H. W. Thompson, of Cardiff University. The plants were found to be very heavily attacked by *Heterodera schachtii* in early stages of development.

The infected field was visited a week later when further observations were carried out. The field was under cultivation as a market garden and had been in the hands of the present owner for the past three years. Previously it had been used as a market garden cropping a large variety of plants, among which peas were included. In 1929 peas were grown on a considerable area, part of which had been cleared of bushes and young trees, and the remainder cleaned as far as possible from a heavy growth of couch grass. That season the pea-crop was poor and the plants were stunted in some parts of the field. In the following year, 1930, peas were grown again on the same plot of land while the remainder of the field was used for potato-growing. Disease symptoms were more marked on this occasion and extended over a larger area. The potatoes also were poor.

In the present year, of the five varieties of peas being grown, three were apparently unaffected, *i.e.*, those grown on the strip of land which had been cleared of bushes, and on the opposite side of the plot, while the two middle varieties, " Daisy " and " Rent-payer," both second

earlies, showed very marked symptoms of disease. Situated on a slope, the field was traversed by a slight ridge about half way down, which cut at right angles across the rows of peas. A curious feature of the infection was that it apparently existed only in the portion below the ridge, which formed a clear line of demarcation between healthy plants and plants showing every symptom of disease. Further, between the stunted and yellow-leaved patch of " Daisy " and the even poorer area of " Rent-payer," four or five rows of the latter variety showing normal growth and colouration extended from the ridge almost to the bottom of the field. These plants resembled those on the upper portion of the field in every particular and were about three times as tall as the heavily infested plants on either side of them.

Microscopical examination of the roots of the affected plants showed that the maturing female nematodes were just beginning to show on the surface of the roots. On the bad plants they were extremely numerous, and the roots were few, soft and brownish in colour, and completely devoid of tubercles. The apparently healthy rows of " Rent-payer " showed only a slight nematode infection and a normal amount of tubercle development, while an examination of plants of both affected varieties above the ridge failed to reveal any evidences of eelworm attack. A distinct blackening of the stem, very suggestive of fungus attack, occurring just above soil level, was an almost constant feature in the infested plants. A fungus growing on some attacked plants which had been kept in water in the laboratory, was examined by Mr. J. Rees of Cardiff University and proved to be a *Fusarium* sp.

Many varieties of weeds, including couch grass, were examined but no eelworm infection was found upon them. However, since the nematodes on the roots of the peas were at an early stage of development it seems possible that slight infections might have been present and been overlooked in this preliminary examination. A few brown cysts were washed out from soil surrounding the roots of some of the plants which were removed for further observation, and these were found to be of the lemon-shape characteristic of infections on plants other than the potato.

Immediately following the diagnosis of *H. schachtii* on peas in Glamorgan, Mr. L. Ogilvie of Bristol University discovered similar infestations near Worcester and in the Evesham district. Material sent to the Insti-

tute showed that here also the infection was extremely heavy and the district was visited in order that further information might be obtained. By the courtesy of Mr. Ogilvie and Mr. B. O. Mulligan, many fields of peas were inspected and some interesting observations were carried out.

Where infections of *H. schachtii* were present the distribution of plants showing symptoms of disease was in almost every instance patchy, that is, limited areas of varying size showed dwarfed and prematurely dying plants, while the remainder of the crop retained a normal healthy appearance. These infected plants showed an abundance of eelworms on the roots, some in the white, others in the brown " cyst " stage. The roots were usually scanty, soft, brown in colour, and apparently almost dead. *Fusarium martii* var. *Pisi* (previously diagnosed by L. Ogilvie) was constantly present on the eelworm infested plants, the lower portions of the stem being partially or completely surrounded by a ring of blackened tissue. In only one instance was tubercle found on the roots of plants attacked by eelworm, and in this case the eelworm formed only a moderate infection. It was noted, however, that tubercle development was weak even in the healthy plants examined. In this and one other case of a moderate infection there was some proliferation of lateral roots suggestive of a host reaction to the nematode, and the plants appeared less stunted than in the more heavily infested areas.

Four fields showing early yellowing of the foliage proved to be free from eelworm infection, *Fusarium* being present alone, and presumably the sole cause of the damage. It is interesting to note that although the yellowing of the foliage was marked it was not accompanied by the dwarfing so characteristic of the combined attacked of fungus and nematode.

Crop records of the infected fields could only be obtained in two instances, in both of which peas had been grown for several successive years and symptoms characteristic of eelworm infection had previously been noticed.

The writer wishes to acknowledge with thanks the assistance given by Mr. Thompson, Mr. Ogilvie and Mr. Mulligan in providing material and facilities for the study of these very interesting strains, on which further morphological and bionomical studies will be carried out.

PREVIOUS OUTBREAKS.

Although *H. schachtii* has only rarely been recorded as parasitizing peas in Britain, it is well known on this host on the Continent, where, more particularly when associated with the fungus *Fusarium vasinfectum* var *pisi*, it has been known to cause severe damage (Capus 1917).

The first case of *H. schachtii* attacking peas in England was described by Theobald (1912), who, however, did not specify the district in which the infection occurred.   Three subsequent infections have been recorded in the " Monthly Summaries of Plant Diseases," issued by the Ministry of Agriculture.   These occurred in Brecon (Cefn Coed), 1918, and in Cornwall (Truro), and Cambridgeshire (Gamlingay), 1922.   One further entry in the Monthly Summaries is of interest in this connection, the record of two infections occurring on potatoes in Glamorgan (Maesteg and Sully), 1926, in both instances following the culture of peas.

Since this paper has been written two other cases of infections of *H. schachtii* on peas have been reported to the Institute from widely separate districts, namely Hertfordshire (Ware) and Berkshire (Abingdon).

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The Kidney-worm of Swine :

Stephanurus dentatus.

RECENT work has revealed the fact that the kidney-worm of pigs is, in certain countries, of considerable economic importance, and that it has an unexpectedly wide geographical distribution.   This parasite does not make its presence in the living animal as obvious as do intestinal worms, since neither worms nor eggs are voided in the fæces, and examinations of urine, as distinct from fæces, are not often made a matter of routine. The pathological and economic effects of the parasite are therefore all the more insidious.   Investigations on this disease are proceeding in various parts of the Empire, and on this account the Imperial Bureau of Agricultural Parasitology has thought it opportune to prepare the present bibliography and notes.

The bibliography deals mainly with references published in scientific literature, but it is realized that there will probably be many further references in veterinary and agricultural Departmental Reports.   In view of the importance of the subject it would be helpful if the attention of the Bureau might be drawn to any of these.

CLASSIFICATION.

Diesing, who in 1839 described the kidney-worm of swine and named it *Stephanurus dentatus*, states that this nematode was first discovered at Barra do Rio Negro in Brazil by Natterer in 1835 among layers of fat in a domestic pig.   In 1858 it was found in the perirenal fat of pigs in the United States by White who recognized it as *Stephanurus dentatus,* although further material collected by White was described by Verrill in 1870 as *Sclerostoma pinguicola* in apparent ignorance of Diesing's work.

In the following year Cobbold (1871) received material from Morris in Australia which he unhesitatingly identified as Diesing's species.

Since then there has been much confusion in nomenclature, as the table of synonyms will show. The species *dentatus* has been placed at different times in the genera *Strongylus* and *Sclerostoma* where it has led in each case to confusion with Rudolphi's species *dentatus* (1803), for this worm (now known as *Oesophagostomum dentatum*) is also found in pigs. In the absence of rules of nomenclature Cobbold (1879) suggested the specific name *nattereri* in honour of the discoverer. Drabble (1922), regarding the Australian worms as a distinct species, proposed for them the name *Sclerostoma renium*, but Cameron & Clunies Ross (1924) re-examined material from New South Wales and denied the necessity for a new specific name. Tayler (1900) regarded the worm as a *Sclerostoma* and, in view of Rudolphi's species *Sclerostoma dentatum*, argued that *pinguicola* should stand as its name. This argument was rejected by Looss (1904 and 1905), amongst others, and the present accepted position is that the swine kidney-worm should be known as *Stephanurus dentatus* Diesing, 1839. The synonymy may be set out as follows :—

Stephanurus Diesing, 1839.

Stephanurus dentatus Diesing, 1839 (Monotypic).

  Synonymy.—*Sclerostoma dentatum* (Diesing, 1839) Leidy, 1856 ;
    nec Ruldolphi, 1803.

    Sclerostoma pinguicola Verrill, 1870.

    Strongylus dentatus (Diesing, 1839) Dean, 1874 ;
    nec Rudolphi 1803.

    Stephanurus nattereri Cobbold, 1879.

    Strongylus pinguicola (Verrill, 1870) Magalhães, 1894.

    Sclerostoma renium Drabble, 1922.

    Stephanurus morai Almeida, 1928.

The principal characteristic of *S. dentatus*, says this last author, " Is the position of the vulva which is situated near the middle of the body. In our case this characteristic is not found, which enables us to consider this strongyle . . . as a new species." Thus do original errors, repeated in text-books, subsequently lead to confusion, as will be seen (under " Morphology ") below.

GEOGRAPHICAL DISTRIBUTION

As mentioned above, the worm was early recorded from South America, the United States and Australia.   Its distribution, as known at present, is considerably wider than that.   Correspondents have reported to this Bureau that it occurs in Queensland, New South Wales, Fiji, South Africa, the Gold Coast, Seychelles, Trinidad and St. Kitts.   It is described as a serious pest in Java and Sumatra by Hellemans (1911), and is recorded from Annam by Railliet & Henry (1911) and by Bernard & Bauche (1913).   In the Philippines it has been dealt with in several papers (Best, 1914 ; Boynton, 1913 and 1914 ; Newcomb, 1913, and Schwartz, 1925).   As regards the New World, apart from the United States records already mentioned, it is recorded from the Argentine and from Uruguay by Wolffhügel (1911 and 1919), and from Devil's Island by Rousseau (1921), and Cameron (1930) states that " The most important of the nematodes occurring in West Indian pigs is undoubtedly *Stephanurus dentatus.*"   In Africa, while Mönnig (1928) lists it as rare in South Africa, it is plentiful in the more tropical regions.   Thus it has been recorded from Portuguese East Africa (Joyeux, 1924 ; le Roux, 1930 B), Dahomey (Pécaud, 1912 ; Bernard & Bauche, 1913), Angola (Almeida, 1928), French and Belgian Congo and Madagascar (le Roux, 1930 A).   Material has been sent to Professor R. T. Leiper, and is housed in the collection of the Helminthology Department of the London School of Hygiene and Tropical Medicine, from New Guinea (sent by Dr. Heyden), Hong Kong (sent by Mr. F. Davidson) and British Guiana (sent by Mr. H. A. Moonsawmy).   Finally, although hitherto regarded as absent from Europe, it has recently been recorded by Lopez-Neyra (1929) as occurring (4 females and 6 males) in a pig fattened and killed in Granada and probably born and bred there.   Thus it will be seen that the parasite is widely present in tropical and sub-tropical regions where pigs are kept.

The parasite has been recorded from various organs within the host (Leuckart, 1876 ; Hellemans, 1911, and recent authors), including perirenal tissues, pelvis of the kidney, walls of the ureter and adjacent tissues, liver, lungs and spleen, peritoneal and thoracic connective tissues, right heart, portal vein and vena cava.   It can now be regarded as probable that the normal sites are the liver (for larvæ and immature adults) and the tissues associated with the excretory organs (for mature adults) :

in view of the life history described below it is easy to see how other organs might become sporadically infected. The adults come to lie (often in pairs) in cysts or in pockets of pus which communicate with the lumen of the excretory organs. Although normally a parasite of the pig, *Stephanurus dentatus* has been recorded from cattle in the United States, usually from the liver where it probably fails to mature. Spindler (1930) has described an immature form from the neighbourhood of the kidney in a yearling calf. There are specimens in the Helminthology Department of the London School of Hygiene and Tropical Medicine (sent to Professor R. T. Leiper by Mr. C. M. G. Hoyte) from the liver of a cow from the Gold Coast. And Mr. J. L. Stewart, the Bureau's Official Correspondent in the Gold Coast, has reported it from an uncertain situation in a donkey.

MORPHOLOGY AND LIFE HISTORY.

Stephanurus dentatus is a nematode of the strongylid type, with its almost globular mouth-capsule and the bursa surrounding the male tail, but several of its strongylid features are but feebly developed. Females occur almost two inches in length (34 mm.-45 mm.) and the males are a little more than half this size (22 mm.-30 mm.). They are respectively about 2 mm. and 1 mm. broad. The mouth capsule, which is thick-walled, is surmounted by a small external leaf-crown (corona radiata) and by six externally reflected lips ("epaulettes," Skrjabin (1921) calls them) of which the ventral and dorsal are more highly developed. At its base is a variable number of teeth (or six teeth with a varying number of cusps). In the male is a feebly developed bursa with short stout rays, a pair of spicules which may be equal or unequal in length (1 mm. or less) and an accessory piece shaped like a broad arrow-head. Diesing (1839) erroneously described a single spicule and his error has been repeated in numerous text-books, e.g., Neumann (1905), p. 469; Underhill (1920), p. 295. In the female the vulva is near the anus behind which the body ends abruptly in a short stumpy tail flanked on each side by a large globular papilla. Here again, Diesing originally described the vulva as being at the beginning of the posterior half of the body, and although he corrected this error in his "Systema" (1851) and "Revision" (1861A) it has been repeated in the older text-books, e.g., Underhill, *loc. cit.*, and see *S. morai* above (in "Classification"). The two uteri run parallel. The eggs, which measure about 0·1 mm. by

0·06 mm., do not hatch until one or two days after they leave the body of the host, normally in the urine. Another 4 or 5 days elapse before the embryos reach the infective stage, so that there is a period of about a week during which the life-cycle can be effectively broken by the pig farmer. Given conditions of heat and moisture the infective larvæ can live for some months, but dryness and low temperature are equally fatal.

MODES OF INFECTION.

There is some difference of opinion regarding the mode of entry into the body of the host. Bernard & Bauche (1913 & 1914) state that infection is principally through the skin (leading to infection of the excretory organs) and less commonly through the mouth (leading to infection of the liver). Thus at Dahomey all infected pigs showed both perirenal and hepatic lesions, while at Annam, although perirenal lesions were invariably found, only 4 per cent. of infected pigs revealed liver infestations. Wolffhügel (1919) finds himself in complete agreement with this theory. Schwartz & Price (1929), however, state that, while the placing of the larvæ on scarified skin or the nasal mucosa or injecting them subcutaneously or administering them by mouth invariably leads to infection, yet the larvæ reach the liver irrespective of the mode of entry, that they come to the surface of the liver, and that they probably migrate actively thence to the adjoining perirenal fat and to the ureters. The researches of Clunies Ross and of Kauzal (see Ross, 1931) indicate that the larvæ enter through the mouth or actively penetrate the skin with equal facility, that they reach the liver in either case and that they do not leave that organ until they are some 5 or 6 months old. Incidentally, Clunies Ross (1931, Fig. 1) gives a photograph of a pig clearly showing skin-nodules at the site of, and 11 days after the time of, artificial infection : these lesions disappeared in a few days. A somewhat similar photograph is given in Bernard & Bauche (1914). Rousseau (1921) states that in Devil's Island hepatic lesions predominate and are the first to appear.

PATHOLOGY.

Although the worms cause hypertrophy of the tissue surrounding the kidneys and ureters they appear not to cause much ill-health thereby (Ross, 1931). Boynton (1914), however, states that in long-standing cases the actual tissues of the kidney, and practically every cavity of the body,

are invaded. Opinion is divided as to whether this disease causes posterior paralysis in pigs or not. Fletcher (1871) thought so, and American opinion has tended to take this view. But now that it is reasonably certain that all the larvæ pass into the liver and there undergo considerable development, it is obvious that the worm must have a hitherto unsuspected pathogenic importance. As Clunies Ross says (1931, p.31) : " The worm gives rise to great destruction of liver tissue, and may cause serious thrombosis of the blood vessels. Even where this does not lead to the death of the animal, the consequent fibrous formation and liver derangement may lead to serious interference with normal liver function, the effects of which may be shown in stunted growth and abnormal development." And Rousseau (1921) suggests that the poor condition of the pigs in Devil's Island, commonly attributed to malnutrition, may well be due to the severe hepatic lesions caused by this parasite.

PROPHYLAXIS.

As regards prophylaxis, le Roux has well quoted Leuckart's admonition : " Swine should be kept in a less swine-like manner." It is clear from what has been said concerning the life-history of this parasite that where pigs are kept under ideal conditions of cleanliness (e.g., confined in concrete-floored sties that are frequently cleaned) they could not easily pick up or retain the infection. Such conditions rarely obtain, of course, but much could often be done by ensuring adequate drainage and by denying the pigs access to muck-heaps. Since for the infective larvæ moisture is an absolute necessity, drainage is an important factor. Where sties are cleaned, the frequency of cleaning is also important. The egg passed in the urine becomes an infective larva in a week or rather less ; so that even where the ideal sty is thoroughly cleaned only once a week (or less frequently) the pigs may still continue to pick up infection. Various prophylactic measures are suggested in detail in le Roux's paper (1930B) which should be consulted. Therapeutic measures, for the present at least, are out of the question.

ECONOMIC IMPORTANCE.

Apart from its pathological effects the parasite is economically important in that it renders the kidneys unfit for consumption. Writing of this parasite in the West Indies Cameron (1930, p.79) says that " It causes the

condemnation of a large proportion of kidneys." Moreover, where there is a high standard of meat inspection (as in England), carcasses with the kidneys removed may not be acceptable. According to Clunies Ross (1931) this has recently become an important factor in relation to Australian exports to Great Britain.

Within the Empire, Australia (except the more southerly regions) is worst affected. Kauzal (1930) has published some striking statistics relating to New South Wales. He shows that, of 58 pigs examined, 11 were infected in the liver and 5 in the lung. Furthermore, of 953 pigs examined only for perirenal infection, 230 (or 24·2 per cent.) were infected. However, from Kauzal's paper and from the publications of Clunies Ross, it is clear that Australia is fully alive to the problem and is taking active measures to deal with it. Some other tropical and subtropical parts of the Empire may not yet realize how serious this parasitic infection may be : hence these notes and the appended bibliography.

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B.G.P.

New Hosts of *Anguillulina dipsaci* (Kühn, 1858) Gerv. & v. Ben. 1859, with some notes and observations on the Biology of the Parasite.

By T. GOODEY, D.Sc.

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ABOUT the middle of June, 1931, the writer received from the Ministry of Agriculture Plant Pathological Laboratory some diseased specimens of carrots which had been growing at Chatteris, Cambridgeshire, where they had been obtained by Mr. Thomas of the School of Agriculture, Cambridge. Microscopic examination showed that they were attacked by *Anguillulina dipsaci*, and since this is the only record of the parasite on this host or, in fact, on any member of the natural order, Umbelliferæ, it has been thought advisable to give an account of the chief symptoms of the disease shown by the plants.

Symptoms.—The plants were fairly young ones and had roots from 2 to 3 ins. long, whilst the tops were from 4 to 6 ins. in height.

(i) On one or two roots the top ¼- to ⅜-in. was bleached and the surface showed longitudinal fissures. This region is really a stem structure, not root, being the swollen hypocotyl of the stem. The parasites were found in the diseased areas.

(ii) The broad bases of the leaf-stalks showed thickenings and a blistered appearance of the epidermis. Several plants exhibited much thickening of the leaf-stalk for some distance above the base accompanied by twisting and coiling where the leaf-blades began to arise. As a consequence of the attack at the base of the leaf-stalks their attachment to the crown of the root had become weakened with the result that in

many cases the whole tuft of leaves had separated completely from the root.

(iii) One or two specimens showed local gall-like swellings of the leaf-stalk in addition to the thickening and twisting noted above.

Adults, larvæ and eggs of the parasite were found in abundance in the affected parts. Some of the diseased plants were photographed, and are reproduced in the accompanying plate so as to show the characteristic malformations produced.

The rotation of crops on the field where they were growing had been carrots and potatoes alternately for four years. No evidence was forthcoming, however, as to the occurrence of disease on either of these crops in previous years.

The discovery of the parasite on carrots affords an opportunity of putting on record certain notes on the host-list presented in the writer's paper published in the JOURNAL OF HELMINTHOLOGY at the end of 1929 and of adding some other hosts which have been found by other workers and by the writer since that was issued. The following list supplements that of 1929 :—

Host Plant.	Common Name.	Nat. Order.	Observer. Date.
Pisum arvense	Field pea	Leguminosæ ...	Theobald, 1900
Dianthus barbatus	Sweet william ...	Caryophyllaceæ ...	Wilson, 1930
Ænothera Fraseri	Evening primrose ...	Onagraceæ	,, ,,
,, ,, var. *Youngii*	— ...	,, ...	,, ,,
Solidago canadensis ...	Golden rod	Compositæ	,, ,,
Phlox divaricata	— ...	Polemoniaceæ ...	,, ,,
,, *suffruticosa*	— ...	,, ...	,, ,,
Schizanthus retusus ...	— ...	Solanaceæ	,, ,,
,, *wisetonensis* ...	— ...	,, ...	,, ,,
Ipomea batatas	Sweet potato	Convolvulaceæ ...	Steiner, 1930
Amsinckia intermedia ...	— ...	Boraginaceæ ...	,, ,,
Campanula persicifolia ...	— ...	Campanulaceæ ...	This record
Primula japonica	— ...	Primulaceæ ...	,, ,,
Cheiranthus allioni, var. " moonlight "	— ...	Cruciferæ	,, ,,
Kniphofia (erecta ?) ...	Red hot poker ...	Liliaceæ	,, ,,
Hieracium Pilosella ...	— ...	Compositæ	,, ,,
Daucus carota	Carrot	Umbelliferæ ...	,, ,,
Lolium italicum	Italian rye grass ...	Graminæ	Rostrup, 1913

A few notes are called for relative to certain necessary corrections in the earlier list and concerning the hosts listed above. *Pisum arvense* was unfortunately omitted from the earlier list as Theobald's work was at that time largely unknown to the writer.

Ormerod, 1890, should be cited as authority for *Brassica rapa* (turnip), and Ormerod, 1891, for *Vicia faba* (field bean) instead of Ritzema Bos, 1888-92, as given for both plants in the earlier list.

The garden plants recorded by Fox Wilson were all found to be susceptible to the strain of the parasite attacking border phloxes. For information concerning *Campanula persicifolia* the writer is indebted to Fox Wilson, in whose garden infected plants were originally found. At a later date he set up an infection in a plant with parasites from a diseased phlox. The same investigator has informed the writer that *Primula japonica* has been known as a host of the parasite at Wisley since 1924, though it has not previously been put on record. The *Kniphofia* material was also sent for examination by Fox Wilson. It showed damage at the junction of the leaf bases with the root stock, and here the parasite was found in considerable numbers. The specific name " *erecta* " is queried, as Fox Wilson was unable to find a distinct species under this name and looks upon it as merely a nurseryman's catalogue name.

For the *Cheiranthus allioni*, var. " moonlight," material the writer is indebted to Mr. Hudson of the Herts' Agricultural Institute, Oaklands, St. Albans, who submitted it for examination.

Hieracium Pilosella is included in the list as though previously known as a host exhibiting nematode galls on the leaves and suspected by Godfrey (1924) as being due to *A. dipsaci*, it had not actually been proved earlier that this was the species of nematode concerned. Galled plants were, however, collected this year by Mr. W. E. H. Hudson in Berkshire when examination showed that the causal organism was *A. dipsaci*.

PERSISTENCE OF THE PARASITE IN MOIST SOIL.

A matter of some practical importance and theoretical interest is the length of time the parasite can remain alive in moist soil in the absence of a suitable host plant. Closely connected with this is the question of the type of parasitism exhibited by this species ; is it an obligate or a facultative parasite ?

The accumulated evidence of the past 60 years or more points clearly to it being an obligate parasite which cannot reach sexual maturity and

reproduce itself except when living on a suitable host plant. In the absence of such a host it gradually dies out from the soil.

References to the persistence of the parasite in soil under moist conditions are not frequent in the literature dealing with *A. dipsaci*, but there is one comparatively recent paper dealing with the matter which calls for some consideration. Rostrup (1926) published the results of an extensive experiment in which she grew red clover in cement pipes sunk in the ground. In the first year the plants in all 18 pipes became badly attacked by *A. dipsaci*. The pipes were arranged in two rows and in the succeeding years during which the experiment was continued clover was sown in only one pipe in each row, advancing by a pair of pipes yearly. The soil in the remaining pipes was kept free from all kinds of plants. The results obtained may be given briefly as follows :—After 0—4 years the clover became infected in the year of sowing, after 5 years the attack did not occur till the August of the year following sowing, after 6—7 years there was no attack in the year of sowing or the following year, but by repeated sowings the attack showed in the third year. These results are then discussed in their bearing on the place of red clover in crop rotation, but this aspect of the matter does not concern us here.

Assuming no chance contamination of the soil with dried material of diseased clover carrying the parasite in a quiescent condition, the above results are difficult to account for, as we must assume that in a moist medium such as the soil of the pipes sunk in the open ground, the parasites would be in an active and not in a quiescent state.

This implies that in the absence of the host for four or five years the parasite remained viable and in an infective condition in the soil. The question is forced upon one, on what was it living in the soil in the absence of a host plant ?

With a view to obtaining some light on this point, the writer set up an experiment as follows. In March, 1929, a quantity of good loamy soil mixed with a small proportion of leaf mould and sand was partially sterilised by steaming and when cool was put into a number of sterile glass specimen tubes 4 ins. long by $1\frac{1}{4}$ in. wide. To each was then added several hundreds of dried pre-adult larvæ of the parasite freshly taken from the base of diseased narcissus bulbs where they were forming cottony tufts. Before closing the tubes with corks covered with cotton-wool the soil in each was moistened with sterile distilled water so as to

bring it to about normal water content. All the tubes were then placed in a suitable box which was put aside in a cool situation. From time to time a little sterile distilled water was added to the soil in each tube to make good any loss by evaporation.

After 12 months the soil was taken from two of the tubes and extracted with water in a Bærmann funnel, when 6 adult worms were obtained, 5 being males and 1 female. They contained some reserve oil droplets in their intestinal walls but not so many as in the original larvæ as added to the soil. In addition their gonads were not completely developed. After 6 more months another tube was taken and extracted with water, but no worms were obtained ; the same result was forthcoming after two years and two and a quarter years from the beginning of the experiment. The parasites had, in fact, died out from the soil.

The results indicate that in the absence of a suitable host plant the parasite survives but little longer than 12 months in a moist aerated medium. A moist partially sterilised soil, such as that used in this experiment, is not strictly comparable, microbiologically, to an unsterilised soil kept under natural conditions in the open, since the latter, though free from the host plant and weeds, might be presumed to possess a different microflora in its surface layers, including green algæ and moss protonema. It is conceivable that the parasite might be able to subsist on these, but this is merely a surmise and there is no evidence of any kind to indicate that it is at all possible.

Rostrup's results are, in fact, very difficult indeed to understand unless we assume that the parasite was re-introduced accidentally into the soil at various times after the first year of the experiment. This is a possibility which cannot be ruled out since it is conceivable that the seed used might have carried the worms. Cobb (1924) has shown that so-called cleaned and re-cleaned red clover seed may carry the parasite on its seed coats. It is not suggested that the use of infected clover seed affords a complete explanation of Rostrup's results since it fails to account for the delayed appearance of the disease symptoms one or two years after the seed was sown. Unless, however, we allow for some condition which permitted of the re-introduction of the parasite, it is impossible to account for its persistence as a living infective organism in the moist soil. The subject is clearly one which shows

that still further investigations are called for on the bionomics of the parasite.

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Explanation of Plate.

Photographs of Carrots attacked by *Anguillulina dipsaci*.

1. Roots showing cracked and discoloured areas in hypocotyl region.
2. Specimen showing greatly enlarged and twisted leaf-stalk, blistered on surface and splitting at attachment to crown.
3. Specimen showing deformed and tufted appearance of foliage.
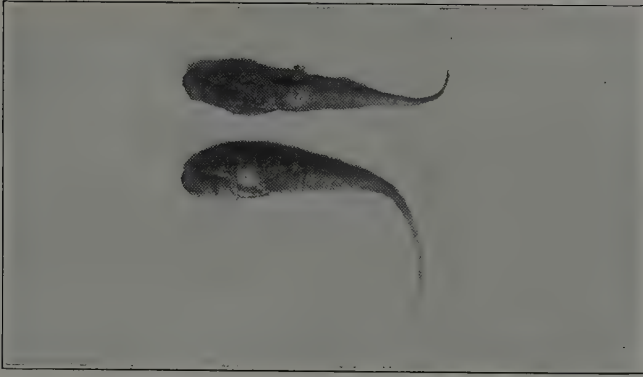
Carrots attacked by *Anguillulina dipsaci.*

On a New Species of *Rhabditis* found in an Ice-Chest.

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In January, 1930, some free-living nematodes belonging to the genus *Rhabditis* were sent to Professor Leiper by Dr. Broughton-Alcock, who had found them in some fungal slime and débris accumulated in the drip from an ice-chest. Herein they are described as a new species of the genus, being named after the finder, and in view of their somewhat unusual habitat, some observations were made on the temperature reactions of the worms. The medium in which they were found proved unsuitable for the purpose of culturing, and at the suggestion of Professor Leiper a suspension in water of a mixture of powdered charcoal and fæces was used, which has proved very successful. Since January, 1930, pure cultures of the nematodes have been kept in this medium in the Department of Helminthology.

Rhabditis broughton-alcocki sp. nov.

Morphology. The cuticle is very finely striated transversely; in some cases the striations are with difficulty seen even under high magnification. The head is not set off distinctly from the body, and bears three bilobed lips which are not very conspicuous. On each lobe there are two papillæ, one fairly large, directed anteriorly, and at its base another smaller one, directed almost at right angles to the longitudinal axis of the worm. Arising from the junctions of the three lips are a number of very delicate setæ or " bristles " which are easily overlooked and are difficult to count, but there are at least three in

each bunch. The buccal tube is of the three-sided type, the sides in optical section being gently curved, and there is a thickening along the junctions of the three sides. The constriction at the base of the tube, typical of the genus, has in consequence a tripartite form, which can be seen from any aspect. It is followed by the usual terminal expansion, which has about the same diameter as the main tube. The lumen of the œsophagus, which is lined with chitin, is also tripartite, and its three radial diverticula correspond in position with the three edges of the buccal tube. There are two well-defined bulbs to the œsophagus and from its anterior end a delicate sheath extends forward and surrounds the buccal tube for about two-thirds of its length.

Principal measurements, in μ.

				Female.	Male.
Length	...	...	...	1200—1900	750—1720
Œs. ...	...	...	...	212—295	170—280
Breadth	...	...	...	50—112	48—100
Tail ...	...	...	...	120—200	40—88
V ...	...	...	...	50%	—
α	...	...	...	22—27	23—28
β	...	...	...	4·9—6·2	4·2—5·8
γ	...	...	...	7·2—12·2	12·6—22·2
Buccal tube		...	...	22—28 $= \frac{1}{10}$	22—30 $= \frac{1}{8}$
Spicules	...	...	...	—	40—60

In the female the genitalia are of the usual type. The vulva is a wide transverse slit, which may be slightly anterior or posterior to the middle of the body. The two opposed uteri contain up to twenty-four eggs. The ovaries, separated from the uteri by the receptacula seminis and oviducts, loop around and terminate about the middle of the body. The intestine, for the anterior half of its length lies to the left of the ovary and uterus. About the middle of the body it curves over dorsally and its posterior half lies on the right side. The tail narrows somewhat abruptly behind the anus and then tapers gradually to a fine point. A pair of small lateral papillæ is situated 30μ to 50μ posterior to the anus.

The male gonad does not call for special comment. The anterior loop occurs about the junction of the first and second fourths of the
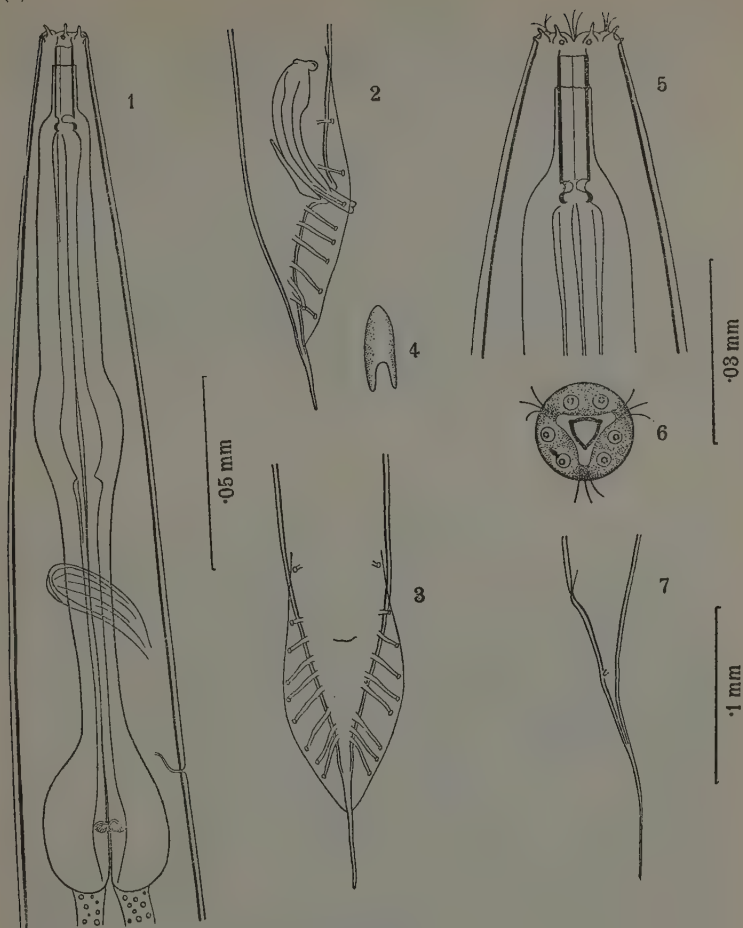
Rhabditis broughton-alcocki sp. nov.

1. Anterior end of male, lateral view. (Oral bristles not drawn.)
2. Bursa, lateral view. 3. Bursa, ventral view.
4. Accessory piece. 5. Anterior end of male, sub-ventral view.
6. End-on view of the head, shewing mouth-opening, lips, papillæ and bristles.
      In the centre the buccal tube is seen in optical section at a deeper focus.
7. Tail of female, lateral view.

body, and cement glands are usually conspicuous. The wide caudal
alæ are supported by nine pairs of papillæ, which are arranged in somewhat
ill-defined groups represented by the formula (1—2) 3, 4 (5—6) + 7, 8, 9.
The second pair lies very close to the first, and in the lateral view of
the bursa it seems to overlie the first ; in ventral view, however, they
are seen to be more or less parallel to one another. The position of
the seventh pair is slightly variable with regard to the anus, but it is
usually a little posterior to it. In a very small percentage of males,
there are only eight pairs of papillæ, the ninth pair being suppressed.
The spicules are sharply curved and strongly built, with lateral ridges
running most of their length, and they terminate distally in a rounded
bilobed process. The accessory piece is about half the length of the
spicules. Its form is depicted in fig. 4.

Temperature Reactions.

The habitat in which the worms were first found, suggested that
they might have a preference for a low-temperature environment. This
is apparently borne out by the fact that they have been successfully
cultured at 7° to 10° C. for nearly two years, and it has been found that
temperatures above 20° are detrimental to the worms ; for example,
when incubated at 25° to 26° they do not live for more than about three
days. At laboratory temperature (19° to 20°) they have been kept
continuously for several months, but they required frequent attention
and addition of food, whereas in the refrigerator they could be safely
left for three months or more without attention. This apparent pre-
ference for low temperatures is not unknown for other members of the
genus *Rhabditis*, for much of Maupas' (1900) experimental work was
carried out at temperatures considerably below 20°, at times as low a
12°, and he attributed the degeneration of his cultures of *R. elegans*
and *R. caussaneli* during the summer months, to the fact that the temper-
ature rose to 23° to 25°.

The ease with which the present species can be cultured at low
temperatures is partly, at any rate, due to the resultant slower rate of
development, which is demonstrated in the following observations.
A quantity of eggs, varying from the one-cell to the 16-cell stage, was

obtained by chopping up gravid female worms, and was divided up into five lots, which were distributed as follows :—

(1)	12 eggs at	...	...	...	5° C.
(2)	7 ,, ,,	...	...	...	19°—20°.
(3)	12 ,, ,,	...	...	...	19°—20° (in light).
(4)	12 ,, ,,	...	...	...	25°—26°.
(5)	15 ,, ,,	...	...	...	37°.

Two days later seven eggs in (1) had developed to the early " tadpole " larval stage, the other five having died or been sterile, whilst in (2), five of the seven were hatched, the other two being dead. In (4), two of the eggs were hatched, eight contained motile embryos, and four were dead, but by the following day all had died. In (5), development had evidently proceeded very rapidly for a short time and then had been checked, for seven of the eggs contained dead larvæ. The others were undeveloped.

On the fifth day five eggs in (1) hatched out, the other two remained unhatched until the following day. In (2) there were now five mature worms, four of which were females, and these began to deposit eggs on the following day.

On the ninth day the larvæ in (1) had only grown to 0·45 mm. in length, *i.e.*, less than half the length of mature worms.

The difference, therefore, between the rate of development at 19°—20° and at 5° is very marked, for in the former case the eggs had hatched and developed to mature forms in the same time taken by the eggs in the latter case merely to become completely hatched. It is of interest to note that development in (3) was somewhat slower than in (2), for on the fifth day the worms were still immature, and deposition of eggs did not begin until the ninth day. Evidently, development was retarded by the presence of light.

It seemed to be of interest to determine the extremes of temperature that could be survived by the worms, and it was found that for short periods at least, temperatures of up to 45° were tolerated. This was determined by means of a Leitz warm stage into which several hanging drop cultures of adult worms were placed successively, the temperature on each occasion being raised one degree higher than previously, and held for a few seconds. In this way also the behaviour of the worms

at different temperatures could be observed.   At laboratory temperature, their movements may be described as leisurely.   Activity increases as the temperature rises to 30° but decreases as this point is passed. At about 34° some of the worms begin a jerky movement which becomes general at 36°, and at 38° it becomes more rapid and is accompanied by a " shivering " motion in some.   Above 40° many of the worms become quite motionless whilst some still exhibit slight movements. Their recovery is by no means uniform, for some regain normal activity from above 40°, according as the laboratory temperature is reached, whilst others remain motionless for more than an hour after cooling. Others again, do not recover at all.   In this respect the time for which the raised temperature was held, was found to be important.   For example, whereas a short period at temperatures up to 45° could be survived by most worms, a period of one hour at 37° was always fatal.

At the other extreme it was observed that only short periods of freezing could be tolerated, and after being embedded for an hour in ice, 90 per cent. were killed.

RELATIONSHIPS.

Morphologically *R. broughton-alcocki* closely resembles *R. duthiersi* Maupas, 1900, particularly with regard to most of the principal measurements, in the three bilobed lips, in the œsophagus with two distinct bulbs, in the disposition of the genital organs, and in the accessory genitalia in the male.   The differences between the two species are :—

(1) The value of β is less in *R. broughton-alcocki*.

(2) Oral bristles and an extra papilla at the base of each of the main papillæ, are present.

(3) The grouping of the bursal papillæ is not so well defined as in *R. duthiersi* and differs to some extent.   In lateral view the second papilla overlies the first.

Biologically the two species are very different in certain features, for whereas in *R. duthiersi* the sex-ratio is 15—20 : 1,000, in the present species the sexes are about equally represented numerically.   Furthermore, hermaphroditism is the normal mode of reproduction in *R. duthiersi*.   No instance of hermaphroditism was observed in the present

species, in the course of controlled experiments in which immature females were isolated and kept alive for a long time.

The following 24 species and 2 varieties have been recorded as new since Mikoletzky's list of 55 species was published in 1921 :—

R. monohysteroides Skwarra, 1921.

R. litoralis Skwarra, 1921.

R. aphodiorum Wülker, 1921.

R. fæcalis Watanabe, 1922.

R. mikoletzkyi Schneider, 1923.

R. Voigti Rahm, 1924.

R. Herfsi Rahm, 1924.

R. lacensis Rahm, 1924.

R. impar Cobb, 1925.

R. parateres Cobb, 1925.

R. plænensis Schneider, 1925.

R. schactiella Skrjabin and Schulz, 1926.

R. donbass Skrjabin, Schulz and Sserbinoff, 1926.

R. microbursaria Steiner, 1926.

R. coffeæ Rahm, 1928.

R. musicola Rahm, 1928.

R. longispina Reiter, 1928.

R. pellio var. *conica* Reiter, 1928.

R. maupasi var. *gongyloides* Reiter, 1928.

R. gracilis Schingarewa, Demidowa and Kudriawzew, 1928.

R. pseudoxycerca Goodey, 1929.

R. de mani Hnatewytsch, 1929.

R. cobbi Hnatewytsch, 1929.

R. elegans Kreis, 1929.

R. octopleura Steiner, 1929.

R. succaris Clapham, 1930.

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On the Occurrence of *Heterodera radicicola* associated with *Heterodera schachtii* as a Field Parasite in Britain.

By Marjorie J. Triffitt, D.Sc.

(*Field Officer, Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.*)

In August of the present year, specimens of young field-grown parsnips and carrots, showing heavily galled roots, were sent to this Institute by Mr. L. Ogilvie. The galls were found to result from eelworm infection, *Heterodera radicicola* being present in considerable numbers in the affected tissues.

Although *H. schachtii* has been known to infect hops in Britain since 1895, and potatoes since 1913, and has since become generally distributed in Britain as a parasite of economic importance attacking potatoes, and recently peas, *H. radicicola* has hitherto only been known to infect glasshouse crops, chiefly tomatoes and cucumbers, in this country. Hence the occurrence of a well established infection of this parasite, which, according to information received by Mr. L. Ogilvie from the growers, seemed to be of several years standing, was of great interest.

The author wishes to acknowledge with thanks the assistance given by the staff of the Long Ashton Agricultural and Horticultural Research Station, and by Mr. L. D. C. McLees and Mr. W. Crisp, County Agricultural and Horticultural Organisers, in arranging facilities for a visit to the infected area and in carrying out the observations detailed below.

The infected field, near Bromham in Wiltshire, was divided into a number of small plots on which a large variety of market garden crops were being grown. Most of the surrounding country was known to be very heavily infected with *H. schachtii*, and in a portion of the field

in question potatoes planted in the spring had been so unsatisfactory as to be early replaced by carrots.

The plot in which parsnips had previously been found to be infected with *H. radicicola* was first examined. Here the plants were small. but the foliage showed no signs of disease such as wilting or yellowing typical of eelworm infections. The root systems showed undersized tap roots with an abnormal abundance of lateral rootlets, the latter being galled by the nematode. Although very numerous, the galls were not of great size, the majority being less than the size of a pea. All the plants examined showed some infection, although the intensity varied in plants taken from different portions of the plot.

H. radicicola, unlike *H. schachtii*, is usually polyphagous in habit, hence it was expected that, of the many varieties of weeds which were growing in the infected plot, a considerable number would show evidences of eelworm attack. Several specimens of each species were accordingly examined, and a representative collection was removed for more detailed inspection in the laboratory. Only three species were, however, found to be infected, namely groundsel (*Senecio vulgaris*), chickweed (*Stellaria media*), and Shepherd's Purse (*Capsella Bursa-pastoris*), and on these only a few small galls were found. But as the number of individual plants of each species which could be subjected to detailed examination was necessarily small, it must not be assumed that the varieties from which negative results were obtained were immune to attack. A bed of carrots adjacent to the infected parsnips showed no signs of infection, but a few small galls were found on runner-beans and on mangolds which were growing a few yards distant from the parsnips, although lettuce plants which were growing between the rows of beans were unaffected.

Examination of the carrots which about six weeks previously had shown root galls due to *H. radicicola*, failed on this occasion to reveal any signs of this infection, but white-stage females of *H. schachtii* were present in considerable numbers on the roots. These white stage females were rather small and of the " lemon-shaped " type, and were furnished with a rather larger " egg sac " than is usual for *H. schachtii*. Many of the eggs contained by the latter were fully embryonated, and that the females were at a fairly advanced stage of development was shown by the fact that they all assumed the characters of the brown-

cyst within twenty-four hours after being exposed to the air.

This infection is of particular interest in that it appears to be the first known case of *H. schachtii* attacking carrots.   Further, the occurrence of *H. radicicola* and *H. schachtii* consecutively upon the same host is unusual and the disappearance of *H. radicicola* remains to be explained. Finally, since this land was known to be heavily infected with a strain of *H. schachtii* attacking potatoes, it must be assumed either that two strains of the nematode exist together in the same soil, the one specialised for potatoes, the other for carrots, or that a single strain exists which is capable of attacking both hosts.   Since strains of *H. schachtii* specialised for potatoes have hitherto proved to be either totally incapable of transmission to other hosts or transmissible only with difficulty and to a small extent, the fairly intense infection on the carrots suggested that some common weed which grew constantly on the land might also be susceptible to infection and might act as a kind of " transitional host."   That is to say, a very slight infection might have been produced on the weed, and the individuals resulting from that infection might have so far lost their specialisation for potatoes as to be able to attack the carrots with comparative ease and hence produced the moderate infection which was found on the carrots in the absence of potatoes· A careful examination of the weeds on this plot, and also on a neighbouring field where potatoes had been very heavily infested this season, failed to reveal any such infection, but since the examination was carried out late in the season it seems possible that any cysts which might have been formed might already have dropped from the roots ;   further observations are needed to elucidate this point.

Some glass-houses used for tomato and cucumber cultivation on a commercial scale, situated some distance from the field infected with *H. radicicola*, seemed to indicate a possible source of this infection.   Only a few small galls were, however, found on the cucumbers, while a slightly heavier infection existed in one of the tomato houses.   The grower had noticed much heavier infections in previous years but stated that the tomato and cucumber soil was not distributed among the local small-holders but was used exclusively in his own market garden adjoining the glasshouses.   Except for the possibility of accidental mechanical transmission of soil, as for example on the boots of labourers, the glasshouses must therefore be excluded from the probable sources of infection.

Other possible means by which the parasite may have been introduced are, the planting out of infected glasshouse-grown seedlings, and the use of contaminated potato bags, as for instance, bags which have been used for the transport of Spanish or other imported potatoes which might easily retain fragments of infected soil.

The potential economic importance of the establishment of *H. radicicola* as a field parasite in Britain will readily be appreciated in view of the spread of *H. schachtii* during the last fifteen years. Moreover, although *H. schachtii* usually confines its attack in any single area to one or two host species, *H. radicicola* rarely specialises upon any single plant, and the fact that it attacks weeds causes its spread and multiplication to be even more rapid than those of *H. schachtii*, while no crop of economic importance in this country is known to be immune to its attack.

On the Longevity of *Fasciola hepatica* in Experimentally Infected Rabbits.

By R. F. MONTGOMERIE, B.Sc., Ph.D., F.R.C.V.S.

(*Veterinary Adviser, School of Agriculture, University College of North Wales.*)

DURING recent years the writer has had occasion to infest many rabbits with cercarial cysts of *Fasciola hepatica*. In all but three instances the infested rabbits have been killed within about ten weeks of the commencement of the experiment. These three rabbits remained infested over a long period and are the subjects of this note. They were kept under conditions which appeared to exclude all opportunity for further fluke infestation and no accidental infestation has been observed among the considerable number of similar rabbits used in other experiments during these years.

EXPERIMENTAL DATA.

Rabbit No. 20 (1927).

Infestation. Six cercarial cysts fed 26th January, 1927.

Observations. Fæces were examined for liver fluke ova at weekly intervals. None were observed until 29th March, 1927 (ninth week). On that date very few fluke ova were seen but on the eleventh week they were numerous, 100 ova per gram of fæces. The number of fluke eggs gradually increased until the twenty-first week (21st June, 1927)

when the count was 833 per gram. Thereafter the number of eggs gradually decreased and on the twenty-sixth week (9th August, 1927) was 200. The egg counts remained at or about this level until fifty-six weeks had elapsed since infestation. During the following week the rabbit evinced symptoms of a concurrent disease and the egg count rose to 566. On the 3rd of March, 1928, it was found dead and four flukes were recovered on post-mortem examination.

Rabbit No. 9 (1928).

Infestation.   Forty cercarial cysts fed on 5th February, 1928.

Observations.   The fæces were examined at weekly intervals until 12th November, 1928, and thereafter only occasionally until 22nd March, 1929, when regular weekly examinations were recommenced. Fluke ova were first observed eight weeks after infestation. The count rose to its highest level at the eighteenth week (766 ova per gram 13th June, 1928) and thereafter gradually fell, to become almost stationary at about 200. One year after infestation (22nd March, 1929) it was 533, and it remained at about this figure until the rabbit died three years and one month from the commencement of the experiment (8th March, 1931). Eleven liver flukes were recovered on post-mortem examination.

Rabbit No. 5 (1928).

Infestation.   Fifteen cercarial cysts fed 16th September, 1928.

Observations.   Eggs of the liver fluke were first detected nine weeks after infestation but the record relating to further counts have been lost This rabbit was accidentally killed two years and seven months after infestation and seven liver flukes were recovered on post-morten examination.

Discussion.

As far as the writer is aware long continued infestation of rabbits with *Fasciola hepatica* has not previously been recorded. One of these rabbits was infested for a period of three years and one month. In the two cases in which periodic counts were made the maximum count was recorded relatively early (21st and 18th week of infestation) and during a long period it was almost stationary. This does not suggest any gradual diminution in the number of infesting flukes.

Hutyra and Marek state, presumably regarding the infestation of sheep, " The flukes remain in the liver for a period of from three to five years. Railliet, Moussu and Henry found them after three years, and Thomas after five and one-quarter years in animals that had no opportunity to become reinfested during the period. The majority of the flukes, however, leave the liver in from nine months to one year, . . ."

A visit to almost any slaughterhouse makes it obvious that *Fasciola hepatica* does not continue to infest cattle for a long period. The livers of two and a half years' old cattle very commonly show evidence of severe infestation without the presence of a single fluke.

The average weight of fæces passed by Rabbit No. 9 was found to be 190 grammes per week. Approximately, the average egg count for the 152 weeks during which this rabbit was passing fluke ova was 450 per gram. It would seem that during the three years of infestation this rabbit passed approximately 13,000,000 eggs, and if eleven was the maximum number of flukes present, each would be credited with laying 1,181,000 ova.

Summary.

Three rabbits lived for more than one year from the date of their being artificially infested with *Fasciola hepatica* :—

Rabbit No. 20. Fed six cercarial cysts ; died one year one month month later ; four flukes recovered.

Rabbit No. 9. Fed forty cercarial cysts ; died three years 1 month later ; eleven flukes recovered.

Rabbit No. 5. Fed fifteen cercarial cysts ; killed two years seven months later ; seven flukes recovered.

Periodic counts of the fluke ova being passed by Rabbits Nos. 20 and 9 were made. They did not suggest any gradual dying off of the infesting flukes.

REFERENCE.

HUTYRA & MAREK, 1926.—" Special Pathology and Therapeutics of the Diseases of Animals," Vol. II, p. 471.

On Two New Species of Nematodes from the Scottish Red Deer.

By THOMAS W. M. CAMERON, M.A., D.Sc., M.R.C.V.S.

(Lecturer in Helminthology in the University of Edinburgh.)

DURING the examination of an abnormal specimen of the Scottish Red Deer (*Cervus elaphus*) in the winter of 1930, my colleague, Mr. W. C. Miller, M.R.C.V.S., discovered several specimens of a bursate nematode lying on the connective tissue between the latissimus dorsi and the external intercostal muscles. Struck by the unusual habitat of such a worm, search was subsequently made in similar situations in other deer, and in two animals the same parasite was found.

Both sexes are thin, slender forms, the female measuring about 5·5 cm. long by 0·2 mm. wide, while the male is about 3·8 cm. long by 0·15 mm. wide. The worms were brown in colour when fixed ; and the skin is faintly striated transversely. The mouth is a simple pore communicating with a simple muscular œsophagus which is about 0·6 cm. long in the female and 0·5 cm. in the male.

The female genitalia is double, the uteri being parallel and communicating with the vulva by means of a long simple ovejector. The vulva is a transverse slit situated 0·2 mm. from the anus (Fig. 1) ; and the anus is situated 0·07 mm. from the tip of the bluntly pointed tail.

The male bursa is entire (Fig. 3) with no dorsal or lateral lobes, and it contains a typical series of rays. The ventral rays (Figs. 2 and 3) which are short and blunt, lie close together and point in an anterior direction. The lateral rays also lie close together, the externo-lateral being only about half the length of the other two. The dorsal ray is

split almost to its broad base and the resulting branches each carry a small internal branch.   The externo-dorsal ray is entirely separate from the main dorsal stem although it lies close beside it.   The spicules are equal, stout, and somewhat blunt.   They are of a dark brown colour and are alate.   They measure about 0·2 mm. long by 0·015 mm. broad. A small accessory piece is present, pointed at each end but wider in front than behind ; it measures about 0·075 mm. long.   The genital cone is fairly large and carries a pair of lateral projections, each with a small papilla.

This nematode obviously belongs to the family Metastrongylidæ but it seems sufficiently distinct from any of the known forms to be placed
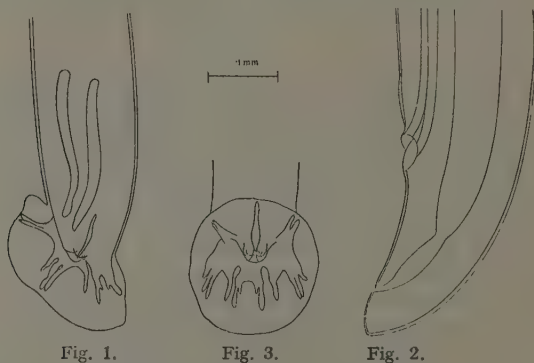
Fig. 1.   Fig. 3.   Fig. 2.

Elaphostrongylus cervi, gen. et sp. nov.

Fig. 1.   Tail of female.
Fig. 2.   Lateral view of tail of male.
Fig. 3.   Ventral view of bursa and accessory piece.

in a new genus.   Accordingly the name *Elaphostrongylus cervi* gen. et sp. nov. is proposed for it.

The second species of nematode was found in the abomasum and duodenum of the Red Deer on a number of occasions.   It appears to be by no means uncommon and to occur in considerable numbers.

The female is 5·5 mm. to 6 mm. in length by about 0·1 mm. in width ; the male is about 4·5 mm. to 5 mm. long by 0·08 to 0·1 mm. wide.   The mouth is simple and the œsophagus is 0·45 mm. to 0·5 mm. long   The skin

carries longitudinal striations with very fine transverse striations crossing them ; the tip of the female tail, however, is more conspicuously striated. The cervical papillæ are small and situated about the level of the middle of the œsophagus, just in front of the excretory pore.

The tail of the female (fig. 4) is generally bent ventrally and is slightly swollen at the tip. The genitalia is double. The ovejectors are typical and opposed, opening by a posteriorly directed vagina which communicates with a transverse naked vulva situated 1·2 mm. from the tip
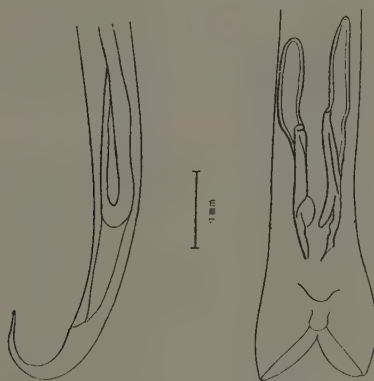
Fig. 4.   Fig. 5.

Ostertagia cervi, sp. nov.

Fig. 4. Tail of female. Fig. 5. Tail of male.

of the tail, *i.e.*, dividing the body in the ratio of 5 : 1. The anterior ovarian tubule is typical but the posterior tubule is not functional and is atrophied. This feature is absolutely constant in all the females examined—several hundreds. The eggs are of the typical trichostrongyle type and are morulated when in the uterine stage. About six of these eggs are found at the same time in the anterior uterus. The anus is 0·15 mm. from the tip of the tail.

The male has a typical trichostrongyle bursa with the lateral lobes separated dorsally and the dorsal lobe distinct and separate. Small prebursal papillæ are present. When spread out (fig. 6), it is seen

that all the rays (except the externo-lateral) reach the edge of the bursa and have graceful outlines. The latero-ventral is turned towards the ventro-ventral. The externo-lateral ray is more or less straight, but the other two lateral rays and the externo-dorsal are bent dorsally and about equally spaced from each other. The main dorsal stem is split into two branches, each being bifurcated : the outer bifurcation is S-shaped and longer than the internal. There is a cuticular swelling dorsal to the ano-genital opening and this is supported by two slender rays.

There is no accessory piece present. The spicules (fig. 5) are equal and similar in general appearance. They measure about 0·2 mm. long and are attached anteriorly to voluminous sac-like structures. In shape they are somewhat irregular but carry an outer sigmoid branch which has a plate-like termination, and an inner smaller pointed branch.
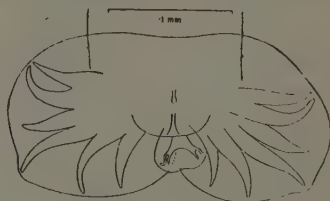
Ostertagia cervi, sp. nov.
Fig. 6. Bursa of male.

This species is tentatively placed in the genus *Ostertagia* because of the presence of an " accessory bursal membrane." It differs from the other similar forms reported from deer in, *inter alia*, the peculiar atrophy of the posterior ovarian tubule. This feature is sufficient to differentiate it from most other species of trichostrongyles in ruminants, with the exception of *Ostertagia harrisi*, reported last year by Le Roux from the Bushbuck (*Tragelaphus sylvaticus*). It differs from this species in the absence of an accessory piece and in the shape of the bursa, spicules, and female tail. Accordingly the specific name *O. cervi* sp. nov. is proposed for it.

REFERENCE.

Le Roux, P. L., 1930.—" On Two New Helminths from the Abomasum of the Bushbuck in Zululand," *16th Rept. of Dir. Vet. Serv., Pretoria,* pp. 233-241.

IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY.

NOTES AND MEMORANDA

No. 4.

The Helminth Parasites of Deer.

IN the course of searching for references to helminth infections in a species of deer, at the request of one of the Bureau's correspondents, it became apparent that the great majority of the helminths either were parasites of sheep and cattle also, or were closely related thereto. In view of the further fact that some deer are of considerable economic importance and are widely scattered over the surface of the earth, it was decided to extend the scope of the search so as to include all deer from which helminthic parasites have been recorded. This information has here been tabulated, with the addition of some necessary comments and a list of the relevant references.

DISTRIBUTION AND NOMENCLATURE OF DEER.

The term " Deer " is here used as co-extensive with the zoological family *Cervidæ*, ruminants in which annually-shed bony antlers are (almost universally) borne by the male (and, in the case of Reindeer, by the female also) and in which a gall-bladder is typically absent. The family is represented in all the countries of the world except Australia, Africa south of the Sahara, and some small islands. In the list appended to this memorandum are included 11 genera : in addition to the three genera occurring in Europe, *Cervus*, *Capreolus* and *Dama*, there are *Alces* and *Rangifer* (Circumpolar), *Axis*, *Rucervus* and *Rusa* (Asiatic), and *Blastocerus*, *Mazama* and *Odocoileus* (American). The more detailed

distribution of each species is given on pp. 16 to 28. This host-list will indicate that the nomenclature of deer is confusing, yet here only such synonyms are listed as occur frequently in the helminthological literature. For some time after Linnæus most deer were included in the genus *Cervus*. Later, most of the American forms were grouped in a genus *Cariacus*. Even to-day there appears to be no complete agreement among zoologists, and for present purposes Flower's classification has been used, as given in the " List of the vertebrated animals exhibited in the gardens of the Zoological Society of London, 1828-1927," Vol. I, " Mammals," London, 1929, pp. ix. + 419. This avoids almost completely a cumbersome trinomial nomenclature without giving grounds for confusion. The trinomial form listed as *Cervus canadensis asiaticus* may possibly be *Cervus songaricus :* sufficient evidence is not available on this point and so the author's designation has been retained.

TABLE I.   POPULAR NAMES OF DEER.

American Fallow Deer (same as Virginia Deer).
Brown Wood-Brocket. (*Mazama simplicicornis*).
Caribou (*Rangifer tarandus terrænovæ*).
Chital (same as Spotted Deer).
Elk (*Alces alces*).
" *Elk* " *in America* (same as Wapiti).
" *Elk* " *in Ceylon* (same as Sambar).
Fallow Deer (*Dama dama*).
Marsh Deer (*Blastocerus dichotomus*).
Mexican Deer (*Odocoileus mexicanus*).
" *Moose* " *in America* (same as Elk).
Mule-Deer (*Odocoileus hemionus*).

Pampas Deer (*Blastocerus bezoarticus*).
Panolia Deer (same as Thamin).
Pygmy Brocket (*Mazama nana*).
Red Brocket (*Mazama americana*).
Red Deer (*Cervus elaphus*).
Reindeer (*Rangifer tarandus*).
Roe Deer (*Capreolus capreolus*).
Sambar (*Rusa unicolor*).
Siberian Roe Deer (*Capreolus pygargus*).
Spotted Deer (*Axis axis*).
" *Stag* " *in America* (same as Red Deer).
Thamin (*Rucervus eldii*).
Virginia Deer (*Odocoileus virginianus*).
Wapiti (*Cervus canadensis*).

The scientific names of the 18 species considered in this memorandum, and their principal synonyms, are combined in one alphabetical arrangement in the host-list. For the convenience of those who may more easily recognize the popular names these are listed (again with some " synonyms ") in Table I. Regarding the popular names, attention may be drawn to some anomalies which are apt to lead to confusion. The deer known in England as the Elk, *Alces alces*, is called Moose in North America, where the name " Elk " is sometimes applied to the Wapiti, *Cervus canadensis*. The same name " Elk " is, in Ceylon, occasionally used for the Sambar, *Rusa unicolor*. Thus " Elk " can refer to three distinct

species of deer. The Virginia deer, *Odocoileus viginianus*, is called " American Fallow Deer " by some of the older writers ; this should not be confused with the Fallow Deer of Europe, *Dama dama*.

ECONOMIC IMPORTANCE OF DEER.

At this point it may be of interest briefly to consider a few species from the economic standpoint. The common Red Deer of Europe has for centuries been an important game animal. In Scotland they were, until latterly, confined to the hills, where they fed chiefly on the rough grass. During the Great War and the recent financial depression, however, deer stalking has been pursued far less extensively, with the result that the deer have multiplied beyond the present restricted capacity of the guns. They are now descending from the hills into the more fertile, cultivated valleys, where they are making serious inroads into the farmers' crops—particularly swedes. Apart from this economic damage, they are picking up, and acting as reservoirs for, the worm parasites of sheep and cattle. The extent to which this is likely to go may be gauged later from Table III and the subsequent discussion. In 1911 Brumpt published a paper, " Les cerfs de la forêt de Chantilly sont décimés par les helminthes," whose title is sufficient to show with what alarm the situation was regarded. The Bureau is indebted to Prof. Brumpt for kindly writing, in reply to a letter, to say that the deer referred to were Red Deer : the parasites recorded in his paper will be found under the heading *Cervus elaphus*. The Roe Deer is also becoming a nuisance in Scotland, where it is damaging trees in the forests.

Turning from deer capable of causing damage to an economically useful species, we may consider the Reindeer, *Rangifer tarandus*. In sub-arctic regions this creature is very numerous, both in the wild state and as a domesticated animal. In the latter respect it is extensively used as a beast of burden, its broadly-splayed hooves being well adapted to walking over snow. Furthermore, it has long been used as food by such people as the Lapps and Samoyeds. In a very interesting article Bederke (1931) shows that Reindeer flesh has recently received the careful attention of the Soviet authorities. During the critical stage of reorganization of peasant farming in Russia there has developed a serious meat famine which is likely to last for some time until the breeding of

beef, the supply of fodder and the organization of transport have reached an efficient economic level. Meanwhile such natural meat reserves as the camel from the central Asiatic desert and the Reindeer from the tundras of the north are being drawn upon.

Bederke states that the flesh of calves about eight months old tastes very like poultry and that of older animals (up to four or five years) like beef ; beyond this age the meat is too dry and sinewy to be pleasant. Upwards of 4 Kgm. of perirenal fat may be found—an important asset in such a climate. The beasts are best slaughtered in autumn. In winter and spring they are in poor condition and the fat deposit is reduced ; in summer they are plagued with various species of œstrid flies. He mentions heavy worm infections and specifically cysticercosis, and incidentally says that Reindeer are very sensitive to carbon tetrachloride, having been killed by doses of slightly more than 1 cc. There are about 2·5 millions of these deer in Russia and the Soviet authorities are establishing large collective Reindeer farms ; six already established contain in the aggregate nearly 14,000 head of deer. The widespread myiasis, anthrax and helminthiasis among Reindeer have become, at least for Russia, problems of major economic importance. The list of helminths given on pp. 26 to 27 under the heading *Rangifer tarandus* is of considerable length ; most of these records are for northern Russia but Hadwen (1922) has reported similar heavy infestations from the Reindeer of Alaska.

Helminth Parasites of Deer.

The helminth parasites of deer may now be considered in some detail. They are listed under the three main groups, flukes, tapeworms and roundworms, on pp. 5 to 11. The usual location in the body of the host is mentioned after the name of each parasite, and below it is a list of the deer from which it has been recorded. References to the actual records are given (p. 16 *et seq.*) under the name of the deer. So many synonyms are involved that it would be inconvenient to include them all in the list. On many of the species some comment is desirable, however, and where confusion would otherwise result synonyms will be mentioned in the course of the comments, see pp. 11 to 13.

TREMATODA.

BALANORCHIS ANASTROPHUS Fischoeder, 1901   ...   3rd Stomach.
    Blastocerus dichotomus.

DICROCOELIUM DENDRITICUM (Rudolphi, 1819) Looss, 1899...   Liver.
    Capreolus capreolus.
    Cervus elaphus.
    Dama dama.

FASCIOLA HEPATICA Linnæus, 1758   ...   .   Liver.
    Capreolus capreolus.
    Cervus elaphus.
    Dama dama.

FASCIOLA MAGNA (Bassi, 1875) Stiles, 1894 ...   .   Liver.
    Cervus canadensis.
    Cervus elaphus.
    Dama dama.
    Odocoileus virginianus.
    Rusa unicolor.

PARAMPHISTOMUM CERVI (Schrank, 1790) Fischoeder, 1901   Stomach.
    Alces alces.
    Capreolus capreolus.
    Cervus elaphus.
    Dama dama.
    Rucervus eldii.

PARAMPHISTOMUM LIORCHIS Fischoeder, 1901   ...   ...   Stomach.
    Blastocerus bezoarticus.
    Blastocerus dichotomus.
    Mazama americana.
    Mazama nana.
    Mazama simplicicornis.
    Odocoileus mexicanus.

PARAMPHISTOMUM ORTHOCOELIUM Fischoeder, 1901 ...   ...   Stomach.
    Rucervus eldii.

ZYGOCOTYLE CERATOSA Stunkard, 1917   ...   .   Cæcum.
     Blastocerus dichotomus.

CESTODA.

CITTOTÆNIA DRATCHYNSKII Romanovitch, 1915   ...   Small intestine.
     Rangifer tarandus.

ECHINOCOCCUS GRANULOSUS (Batsch, 1786) Rudolphi, 1905
     Larval Form, Hydatid (adult in canines)...   Liver, Lungs, etc.
        Alces alces.
        Capreolus capreolus.
        Rangifer tarandus.

MONIEZIA ALBA (Perroncito, 1879) R. Blanchard, 1891   ...   Intestine.
     Capreolus capreolus.

MONIEZIA CRUCIGERA (Nitzsch in Giebel, 1866) Railliet, 1893   Intestine.
     Capreolus capreolus.
     Cervus elaphus.

MONIEZIA EXPANSA (Rudolphi, 1810) R. Blanchard, 1891   ...   Intestine.   ·
     Blastocerus bezoarticus.
     Capreolus capreolus.
     Cervus elaphus.
     Mazama americana.
     Mazama nana.
     Rangifer tarandus.

MONIEZIA OBLONGICEPS Stiles & Hassall, 1893   ... ·   ...   Intestine.
     Mazama sp.

MULTICEPS MULTICEPS (Leske, 1780) Hall, 1910
     Larval form, *Coenurus cerebralis* (adult in canines)   ...   Brain.
        Capreolus capreolus.
        Rangifer tarandus.

TÆNIA HYDATIGENA Pallas, 1766
     Larval Form, *Cysticercus tenuicollis* (adult in carnivores).
        Alces alces.
        Axis axis   ...   . Liver, mesentery.
        Capreolus capreolus   ...   . Brain, liver, mesentery.
        Cervus elaphus ...   . Liver, mesentery.

Dama dama.
Mazama americana   ...   . Liver, mesentery.
Mazama simplicicornis.
Odocoileus hemionus   ...   .   Viscera, heart.
Odocoileus mexicanus ...   .   Peritoneum.
Odocoileus virginianus.
Rangifer tarandus   ...   . Liver, mesentery.
Rusa unicolor.

TÆNIA KRABBEI Moniez, 1879
Larval Form, *Cysticercus tarandi* (adult in *Canis*
familiaris)   ...   .   Musculature.
Capreolus capreolus.
Rangifer tarandus.

TÆNIA OVIS (Cobbold, 1869) Ransom, 1913 [?]
Larval Form, *Cysticercus ovis* (adult in dog)
Odocoileus hemionus ...   .   Leg muscles.

TÆNIA RANGIFERI (Grüner, 1910)
Larval Form, *Cysticercus rangifer* (adult unknown)   ...   Heart.
Rangifer tarandus.

TÆNIA SOLIUM Linnæus, 1758
Larval Form, *Cysticercus cellulosæ* (adult in man)
Liver, musculature.
Capreolus capreolus.

TÆNIA sp.
Larval Form, Cysticercus   ...   .   Peritoneum.
Axis axis.

THYSANOSOMA ACTINIOIDES Diesing, 1834   ...   . Intestine.
Blastocerus dichotomus.
Capreolus capreolus.
Mazama americana.
Mazama nana.
Mazama simplicicornis.

THYSANOSOMA PYGARGI Kholodkovsky, 1902...   ...   ... Intestine.
Capreolus pygargus.

NEMATODA.

ASCARIS LUMBRICOIDES, Linnæus, 1758   ...   .   Rumen.
      Capreolus capreolus.

CAPILLARIA sp.
      Cervus elaphus.

CHABERTIA OVINA (Fabricius, 1788) Railliet & Henry, 1909
                                        Large intestine.
      Capreolus capreolus.
      Cervus elaphus.
      Dama dama.

COOPERIA CURTICEI (Railliet, 1893) Railliet & Henry, 1909
                                          Small intestine.
      Cervus elaphus.
      Dama dama.

DICTYOCAULUS FILARIA (Rudolphi, 1809) Railliet & Henry, 1907
      Cervus elaphus.

DICTYOCAULUS HADWENI Chapin, 1925   ...   .   Lungs.
      Alces alces.
      Cervus canadensis.

DICTYOCAULUS NOERNERI Railliet & Henry, 1907
      Capreolus capreolus.
      Cervus elaphus.

DICTYOCAULUS VIVIPARUS (Bloch, 1782) Railliet & Henry, 1907
      Rangifer tarandus.

ELAPHOSTRONGYLUS CERVI Cameron, 1931   ... Intercostal connective
      Cervus elaphus.   tissue.

EUCYATHOSTOMUM LONGESUBULATUM Molin, 1861   ...   ...   Cæcum.
      Blastocerus bezoarticus.
      Mazama americana.

GONGYLONEMA SPIRALE Molin, 1857
      Dama dama.

HÆMONCHUS BISPINOSUS (Molin, 1860), Railliet & Henry, 1909   Stomach.
      Mazama nana.

HÆMONCHUS CERVINUS Baylis & Daubney, 1922
> Axis axis.

HÆMONCHUS CONTORTUS (Rudolphi, 1803) Cobb, 1898   Abomasum.
> Alces alces.
> Capreolus capreolus.
> Mazama simplicicornis.
> Mazama sp.
> Odocoileus hemionus.
> Rangifer tarandus terrænovæ.

NEMATODIRELLA LONGISPICULATA Yorke & Maplestone, 1926
> Small intestine.
> Rangifer tarandus.

NEMATODIRUS FILICOLLIS (Rudolphi, 1802) Ransom, 1907
> Small intestine.
> Capreolus capreolus.
> Dama dama.

NEMATODIRUS ROSCIDUS Railliet, 1893.
> Cervus elaphus.

NEMATODIRUS SPATHIGER (Railliet, 1896) Railliet & Henry, 1909
> Small intestine.
> Capreolus capreolus.
> Dama dama.

ŒSOPHAGOSTOMUM VENULOSUM (Rudolphi, 1809) Railliet, 1896   Intestine.
> Capreolus capreolus.
> Cervus elaphus.
> Dama dama.

ONCHOCERCA FLEXUOSA (Wedl, 1856) Railliet & Henry, 1909
> Sub-cutaneous nodules.
> Cervus elaphus.

OSTERTAGIA ASYMMETRICA Ware, 1925...   ...   ...   Abomasum.
> Dama dama.

OSTERTAGIA CERVI Cameron, 1931   ...   Abomasum and duodenum.
> Cervus elaphus.

OSTERTAGIA CIRCUMCINCTA (Stadelmann, 1894) Ransom, 1907
> Abomasum and intestine.
> Rangifer tarandus terrænovæ.

OSTERTAGIA HOUDEMERI Schwartz, 1927   ...   . Stomach.
     Cervidæ (Gen. et sp. incog.)

OSTERTAGIA ODOCOILEI Dikmans, 1931...   ...   ...   Abomasum.
     Odocoileus virginianus.

OSTERTAGIA MOSSI Dikmans, 1931   ...   .   Abomasum.
     Odocoileus virginianus.

OXYURID   ...   .   Cæcum and colon.
     Cervidæ (Gen. et sp. incog.)

PROTOSTRONGYLUS MACROTIS Dikmans, 1931 ...   .   Bronchi.
     Odocoileus hemionus.

PROTOSTRONGYLUS SAGITTATUS (Müller, 1890) Cameron, 1927
     Cervus elaphus.

SETARIA ALTAICA Rajewsky, 1928   ...   ...   Abdominal cavity.
     Cervus canadensis asiaticus.

SETARIA BIDENTATA (Molin, 1858) Railliet & Henry, 1911
     Mazama nana.

SETARIA NUDICAUDA Ortlepp, 1924.
     Cervidæ (Gen. et sp. incog.).

SETARIA TUNDRA Issaitschikow & Rajewsky, 1928   Abdominal cavity.
     Rangifer tarandus.

SKRJABINEMA TARANDI Skrjabin & Mizkewitsch, 1930   Large intestine.
     Rangifer tarandus.

SPIROPTERA VERRUCOSA Molin, 1860   ...   .   Stomach.
     Blastocerus dichotomus.
     Mazama nana.

STRONGYLUS CAPREOLI Rudolphi, 1809...   ...   ...   Renal tubules.
     Capreolus capreolus.

STRONGYLUS sp.
     Cervus elaphus.

SYNGAMUS NASICOLA Linstow, 1899   ...   .   Posterior nares.
     Mazama americana.

TRICHOSTRONGYLUS COLUBRIFORMIS (Giles, 1892) Ransom, 1911
                                          Duodenum.
     Capreolus capreolus.

TRICHOSTRONGYLUS EXTENUATUS (Railliet, 1898) Ransom, 1907

Abomasum.

      Capreolus capreolus.

      Odocoileus hemionus.

      Rangifer tarandus terrænovæ.

TRICHURIS ALCOCKI (Linstow, 1906) Ransom, 1911...   ...   Intestine.

      Rucervus eldii.

TRICHURIS OVIS (Abildgaard, 1795) Smith, 1908   ...   Large intestine.

      Alces alces.

      Axis axis.

      Blastocerus dichotomus.

      Capreolus capreolus.

      Cervus elaphus.

      Dama dama.

      Mazama americana.

      Odocoileus hemionus.

      Rangifer tarandus terrænovæ.

The distomes, *Dicrocœlium dendriticum* (= *D. lanceatum*), *Fasciola hepatica* and *F. magna* (= *Fascioloides magna*) are common parasites of ruminants and other mammals. The other trematodes listed are all amphistomes. The two species from *Rucervus eldii* were recorded as new species by Stiles & Goldberger, 1910. Their *P. papilligerum* (p. 78) has since been reduced to synonymy with *P. cervi*, and their *P. shipleyi* (p. 151) to synonymy with *P. orthocœlium*, in each case by Maplestone (1923, pp. 117, 145 and 203).

Zygocotyle ceratosa is regarded by Fukui (1929, p. 346) as including Diesing's *Amphistoma lunatum* and contains only parasites of birds apart from this record from *Blastocerus dichotomus*. Diesing (1850, p. 406) lists it as discovered in this host by Natterer and adds the comment " Nisi lapsus calami."

The cestodes for which deer are the definitive hosts, *Cittotænia dratchynskii*, 4 species of *Moniezia* and 2 of *Thysanosoma*, call for no special comment with the exception of *Moniezia crucigera*. Of this species the original description is insufficient and the type material lost, according to Stiles & Hassall (1893, p. 86), who add that " It will

probably be better to ignore this specific name and diagnosis entirely.''

The records of *Cysticercus cellulosæ*, the larval stage of *Tænia solium*, in the Roe Deer have been questioned by various authors. Christiansen (1927) shows fairly conclusively that the specimens he examined were really the cysticerci of *Tænia krabbei*, which Moniez (1879) described, from the Reindeer and successfully fed to a dog. Christiansen gives a number of references dealing with this species of cysticercus in the Roe Deer. The larva of *Tænia* sp. recorded by Shipley from *Axis axis* is, he says (1902, p. 8), probably *Tænia hydatigena*.

Ascaris lubricoides in the Roe Deer is recorded by Neveu-Lemaire (1923, p. 265) as *Ascaris ovis*, which is now usually regarded as a synonym of the former. This is apparently the only record in this or any deer ; in sheep also the parasite is extremely rare. The capillaria from the Red Deer is listed by Brumpt (1911, p. 908) as " *Capillaria* n. sp." but no subsequent specific name and description have been found.

Cooperia curticei represents Rudolphi's *Strongylus ventricosus* (1809, p. 222). Travassos (1921, p. 32) refers to it as *Trichostrongylus* (sens. lat.) *ventricosus*, while Yorke & Maplestone (1926, p. 132) regard it as synonymous with *Cooperia curticei*.

Gongylonema spirale Molin, 1857, is a doubtful species. Baylis (1925, p. 47) states that " Molin's (1857) description does not enable *G. spirale* to be distinguished as a valid species, and it may be regarded provisionally as synonymous with *G. pulchrum.*" Similarly, Molin's description of *Hæmonchus bispinosus* is regarded by Ransom (1911, p. 54) as too brief to establish even the genus in which this parasite should be placed.

Nematodirella longispiculata is the name given by Yorke & Maplestone (1926, p. 140) to a nematode described by Romanovitch (1915, p. 451) as *Microcephalus longissime spiculatus*, from the Reindeer. The generic name is pre-occupied by *Microcephalus* van der Wulp, 1873 (one of the diptera) and the original specific name is in an irregular form.

Wedl's description of his *Filaria flexuosa* (1856, p. 122) is also sketchy by modern standards. Taking into consideration the location (". . . in nodules occurring under the skin of deer ") the species probably belongs to *Onchocerca*, according to Railliet & Henry, 1909, p. 128.

Dikmans' oxyurid from an American deer was represented by 40 females only. As the characters of the male tail are essential for the classification of this group he preferred to leave the oxyurid unnamed. Dikmans placed his species *macrotis* directly into the genus *Protostrongylus ;* but the second species listed, *P. sagittatus*, is probably better known as *Synthetocaulus sagittatus*. Cameron (1927, p. 11) pointed out that *sagittatus* should follow the other species of *Synthetocaulus* into the earlier genus *Protostrongylus*. This genus is due to Kamensky, 1905 and not to Leiper, 1908, as some authors have assumed ; no such genus has ever been created by Leiper (*pace* Baylis & Yorke).

It is uncertain where *Spiroptera verrucosa* should be placed. Ransom 1911, p. 103) describes it under this name for convenience but says it probably does not belong to *Spiroptera*. The genus has now fallen into synonymy, and in any case its other species are parasites of birds.

Strongylus capreoli Rudolphi, 1809, is even more vague. He gives a brief description (p. 244) but later (1819, p. 36) includes it among his *species dubiæ*. Its location, in renal tubules, is of some interest.

HELMINTHS EXCLUSIVE TO DEER.

TABLE II.

Paramphistomum liorchis.	Nematodirus roscidus.
	Onchocerca flexuosa.
Cittotænia dratchynskii.	Ostertagia asymmetrica.
Moniezia crucigera.	cervi.
Tænia krabbei (Cysticercus tarandi).	houdemeri.
rangiferi (Cysticercus rangifer).	odocoilei.
Thysanosoma pygargi.	mossi.
	Protostrongylus macrotis.
Dictyocaulus nœrneri.	sagittatus.
Elaphostrongylus cervi.	Setaria altaica.
Eucyathostomum longesubulatum.	nudicauda.
Gongylonema spirale.	tundra.
Hæmonchus bispinosus.	Skrjabinema tarandi.
cervinus.	Trichuris alcocki.
Nematodirella longispiculata.	

Before proceeding to the question of reservoir hosts it may be useful to summarize the numbers of helminths parasitizing deer. There are 8 species of trematodes distributed among 5 genera, 14 spp. of cestodes among 6 genera and 39 spp. of nematodes among 21 genera ; or, in the aggregate, 61 spp. of helminths among 32 genera. In Table II are listed those species of helminths which appear to be exclusively parasites of deer. Even these mostly belong to genera in which other species are

parasites of ruminants. The only genera at present exclusive to deer are *Elaphostrongylus*, *Nematodirella* and possibly *Eucyathostomum*.

DEER AS RESERVOIR HOSTS.

Attention has already been drawn to the fact that many of the worm parasites of deer are also parasites of sheep, cattle and other ruminants. It is obvious that wherever deer and domesticated ruminants have access

TABLE III.

DEER PARASITES found also in					CATTLE.	SHEEP.	GOATS.
Balanorchis anastrophus	...	...	...	...	x	—	—
Dicrocœlium dendriticum	...	...	...	...	x	x	x
Fasciola hepatica	...	...	...	...	x	x	x
magna	...	...	...	...	x	—	—
Paramphistomum cervi	...	...	...	...	x	x	x
orthocœlium	...	...	...	...	x	x	—
Echinococcus granulosus (Larvæ)	...	...	...	x	x	x
Moniezia alba	...	...	...	...	x	x	—
expansa	...	...	...	...	x	x	x
oblongiceps ...	...	...	...	...	—	x	—
Multiceps multiceps (Larvæ)	...	...	...	...	x	x	x
Tænia hydatigena (Larvæ)	...	...	...	...	x	x	x
ovis [?] (Larvæ)	...	...	...	...	—	x	x
solium (Larvæ) ...	...	...	...	...	x	x	x
Thysanosoma actinioides	...	...	...	...	x	x	—
Ascaris lumbricoides ...	...	...	...	...	x	x	—
Chabertia ovina	...	...	...	...	x	x	x
Cooperia curticei	...	...	...	...	x	x	x
Dictyocaulus filaria ...	...	...	...	...	—	x	x
hadweni ...	...	...	...	...	x	—	—
viviparus...	...	...	...	...	x	—	—
Hæmonchus contortus ...	...	...	...	...	x	x	x
Nematodirus filicollis ...	...	...	...	...	x	x	x
spathiger...	...	...	...	...	x	x	x
Œsophagostomum venulosum	...	...	...	—	x	x
Ostertagia circumcincta	...	...	...	...	—	x	x
Syngamus nasicola ...	...	...	...	...	—	—	x
Trichostrongylus colubriformis	...	...	...	—	x	x
extenuatus ...	...	...	...	x	x	x
Trichuris ovis	...	...	...	...	x	x	x
Totals ... 29	...	...	...	23	24	20

to the same pasture the deer will function as reservoir hosts, acquiring parasites from the domesticated animals and distributing them possibly over a wide area. This will apply to at least some of the common parasites. This qualification is added because it is not yet certain to what extent the problem may be complicated by the existence of "Biological Races" like the races of *Ascaris lumbricoides* adapted to different hosts.

It is probable, however, that the great majority of common ruminant parasites found in deer have in each case been recently acquired from domesticated animals, and therefore the question of there being races adapted over many generations to the deer would not arise.   The migration of Scottish deer from the hills into the farmed valleys has already been mentioned.   Here, at any rate, it should be possible to decide whether the deer can seriously be implicated as reservoirs.

Table III consists of a list of parasites of deer which are also to be found in some or all of the common domesticated ruminants, cattle, sheep and goats.   The term " Cattle " is used broadly in the sense of domesticated bovines.   Some of the deer parasites, for instance the distomes and most of the larval cestodes, are common to a much larger range of animals and even to man (though here the infections are rare). Hydatid is a case in point, and this parasite is not infrequently found in man in certain parts of the world.   Hydatid could not normally be acquired from deer, of course, but from the definitive hosts, various canines. Given a considerable intimacy with heavily infected dogs, however, the conditions are altogether favourable for human infection.   These conditions are satisfied in the sub-arctic regions where both the Reindeer and the Elk are infested with hydatid.   Bederke (1931) has pointed out that it is almost impossible to bury the carcasses of Reindeer, since the ground is perpetually frozen, and that therefore wolves, foxes and dogs readily disseminate various infections.   It is not known whether hydatid is common amongst the Lapps and Samoyeds ; it certainly is common in man in Iceland, where Reindeer were introduced in the eighteenth century ; and whether the Reindeer has been definitely implicated as a reservoir for hydatid in man, or not, there is sufficient circumstantial evidence to make it a distinct possibility.

HOST-LIST OF HELMINTH PARASITES.

The subjoined host-list of the helminth parasites of deer is as complete as present information allows.   The list is an alphabetical arrangement of the scientific names and principal synonyms of the relevant species of deer.   The synonyms merely refer to the accepted name, under which heading will be found the following information : The author and date of the specific name, and the popular name or names

are on the first line.   Below this are given respectively the synonyms
(if any), the geographical distribution and the parasites, pertaining to
that species of deer.   The parasites are listed in the order : flukes,
tapeworms, roundworms, and alphabetically within any one of these
groups.   After each parasite name appears one or more abbreviated
references to the record of this parasite in this host.   The full references
are arranged alphabetically at the end of the memorandum.   Many
of the records are necessarily traced in the first instance in various text-
books and compilations ; wherever possible, however, the original record
has been found and checked.   If the reader's interest is centred rather
in a particular parasite than in the parasites of a particular host, this
list should be used in conjunction with the previous list in which the
arrangement is under parasites.

B. G. P.

HOST-LIST OF PARASITES WITH REFERENCES ARRANGED
UNDER SCIENTIFIC NAMES OF DEER.

Alce americanus, *see* Alces alces.

ALCES ALCES (Linnæus, 1758) ; Elk, Moose in America.
        Synonymy—*Alce americanus.*
                          Alces machlis.
                          Cervus alces.
        Distribution—Northern Europe, Northern Asia and North America
        Parasites—
                Paramphistomum cervi.
                        Maplestone, 1923, p. 203 (in Europe).
                Echinococcus granulosus.
                        Stiles, 1906, p. 76.
                Tænia hydatigena.
                        Linstow, 1901, p. 282.
                Dictyocaulus hadweni.
                        Chapin, 1925, p. 677 (in U.S.A.).
                Hæmonchus contortus.
                        Ransom, 1911, p. 52.
                Trichuris ovis.
                        Ransom, 1911, p 112 (in U.S.A.).

Alces machlis, *see* Alces alces.

AXIS AXIS (Erxleben, 1777) ; Chital, Spotted Deer.
> Synonymy—*Cervus axis.*
> Distribution—India and Ceylon.
> Parasites—
>> Tænia hydatigena.
>>> Diesing, 1850, p. 489.
>> Tænia sp.
>>> Shipley, 1902, p. 8.
>> Hæmonchus cervinus.
>>> Baylis & Daubney, 1922, p. 337.
>> Trichuris ovis.
>>> Ransom, 1911. p. 112.

BLASTOCERUS BEZOARTICUS (Linnæus, 1758) ; Pampas Deer.
> Synonymy—*Blastocerus campestris.*
>> *Cariacus campestris.*
>> *Cervus campestris.*
>> *Mazama bezoartica.*
> Distribution—South America.
> Parasites—
>> Paramphistomum liorchis.
>>> Fischoeder, 1901, p. 368 (in Brazil).
>> Moniezia expansa.
>>> Ditlevsen, 1914, p. 1129.
>>> Natterer in Diesing, 1850, p. 497 (in Brazil).
>> Eucyathostomum longesubulatum.
>>> Molin, 1861, p. 460 (in Brazil).

Blastocerus campestris, *see* Blastocerus bezoarticus.

BLASTOCERUS DICHOTOMUS (Illiger, 1815) ; Marsh Deer.
> Synonymy—*Blastocerus paludosus.*
>> *Cariacus paludosus,*
>> *Cervus dichotomus.*
>> *Cervus paludosus.*
> Distribution—South America.
> Parasites—
>> Balanorchis anastrophus.
>>> Fischoeder, 1901, p. 375 (in Brazil).

Paramphistomum liorchis.
> Fischoeder, 1901, p. 368 (in Brazil).

Zygocotyle ceratosa.
> Diesing, 1850, p. 406 (in Brazil).
> Fukui, 1929, p. 346.

Thysanosoma actinioides.
> Diesing, 1850, p. 501 (in Brazil).

Spiroptera verrucosa.
> Molin, 1860, p. 964 (in Brazil).

Trichuris ovis.
> Ransom, 1911, p. 112.

Blastocerus paludosus, *see* Blastocerus dichotomus.

Capreolus capræa, *see* Capreolus capreolus.

CAPREOLUS CAPREOLUS (Linnæus, 1758) ; Roe Deer.
> Synonymy—*Capreolus capræa.*
> > *Cervus capræa.*
> > *Cervus capreolus.*

Distribution—Europe and Western Asia.

Parasites—

Dicrocœlium dendriticum.
> Stroh, 1930, p. 387 (in Germany).

Fasciola hepatica.
> Nicoll, 1923, p. 244.
> Stroh, 1930, p. 385 (in Germany).

Paramphistomum cervi.
> Maplestone, 1923, p. 203.
> Nicoll, 1923, p. 244 (in Europe).

Echinococcus granulosus.
> Railliet, 1886, p. 248.

Moniezia alba.
> Kholodkovsky, 1902, p. 145 (in Russia).

Moniezia crucigera.
> Giebel, 1866, p. 259.

Moniezia expansa.
> Nitzsch in Diesing, 1850, p. 497 (in Germany).
> Rudolphi, 1819, p. 144.

Multiceps multiceps.

> Beneden, 1861, p. 321.
>
> Moniez, 1880, p. 83.

Tænia hydatigena.

> Beneden, 1861, p. 321.
>
> Diesing, 1850, p. 489.

Tænia krabbei.

> Christiansen, 1927, p. 270 (in Denmark).

Tænia solium.

> Beneden, 1861, p. 321.
>
> Christiansen, 1927, p. 251.
>
> Dujardin, 1845, p. 633.

Thysanosoma actinioides.

> Blei, 1921, p. 384.

Ascaris lumbricoides.

> Neveu-Lemaire, 1923, p. 265 (in France).

Chabertia ovina.

> Ransom, 1911, p. 37.

Dictyocaulus noerneri.

> Railliet & Henry, 1907, p. 752.

Hæmonchus contortus.

> Nitzsch in Dujardin, 1845, p. 124.

Nematodirus filicollis.

> Ransom, 1911, p. 84.

Nematodirus spathiger.

> Travassos, 1921, p. 30.

Œsophagostomum venulosum.

> Ransom, 1911, p. 47.

Strongylus capreoli.

> Rudolphi, 1809, p. 244 (in Europe).
>
> 1819, p. 36.

Trichostrongylus colubriformis.

> Ransom, 1911, p. 88.

Trichostrongylus extenuatus.

> Ransom, 1911, p. 94.

Trichuris ovis.

> Rudolphi, 1819, p. 17.

CAPREOLUS PYGARGUS (Pallas, 1771) ; Siberian Roe Deer.
> Distribution—Turkestan, Siberia, Manchuria.
> Parasites—
>> Thysanosoma pygargi.
>>> Kholodkovsky, 1902, p. 145 (in Siberia).

Cariacus campestris, *see* Blastocerus bezoarticus.

Cariacus macrotis, *see* Odocoileus hemionus.

Cariacus mexicanus, *see* Odocoileus mexicanus.

Cariacus nambi, *see* Mazama nana.

Cariacus paludosus, *see* Blastocerus dichotomus.

Cariacus rufus, *see* Mazama americana.

Cariacus virginianus, *see* Odocoileus virginianus.

Cervus alces, *see* Alces alces.

Cervus axis, *see* Axis axis.

Cervus campestris, *see* Blastocerus bezoarticus.

CERVUS CANADENSIS Erxleben, 1777 : Wapiti, Elk in America.
> Distribution—North America ; sub-species in Asia.
> Parasites—
>> Fasciola magna.
>>> Stiles & Hassall, 1908, p. 263.
>> Dictyocaulus hadweni.
>>> Chapin, 1925, p. 677.
>>> Dikmans, 1931B, p. 2 (in Wyoming, U.S.A.).
>> Setaria altaica (in " *Cervus canadensis asiaticus.*")
>>> Rajewsky, 1929, p. 41 (in Siberia).

Cervus capræa, *see* Capreolus capreolus.

Cervus capreolus, *see* Capreolus capreolus.

Cervus dama, *see* Dama dama.

Cervus dichotomus, *see* Blastocerus dichotomus.

CERVUS ELAPHUS Linnæus, 1758 ; Red Deer, Stag in America.
> Distribution—Europe, Western Asia, North-west Africa (Algeria and Tunisia).
> Parasites—
>> Dicrocoelium dendriticum.
>>> Nicoll, 1923, p. 244 (in Britain).
>>> Stroh, 1930, p. 389 (in Germany).

Fasciola hepatica.

> Nicoll, 1923, p. 244 (in Britain).

> Stroh, 1930, p. 388 (in Germany).

Fasciola magna.

> Nicoll, 1923, p. 244 (in Britain).

Paramphistomum cervi.

> Fischoeder, 1901, p. 368 (in Europe).

Moniezia crucigera.

> Blei, 1921, p. 384.

Moniezia expansa.

> Blei, 1921, p. 384.

Tænia hydatigena.

> Diesing, 1850, p. 489.

Capillaria sp.

> Brumpt, 1911, p. 908 (in France).

Chabertia ovina.

> Ransom, 1911, p. 37.

Cooperia curticei.

> Rudolphi, 1809, p. 222.

> Travassos, 1921, p. 32.

> Yorke & Maplestone, 1926, p. 132.

Dictyocaulus filaria.

> Brumpt, 1911, p. 908 (in France).

Dictyocaulus noerneri.

> Brumpt, 1911, p. 908 (in France).

Elaphostrongylus cervi.

> Cameron, 1931, p. 213 (in Scotland).

Nematodirus roscidus.

> Brumpt, 1911, p. 908 (in France).

Œsophagostomum venulosum.

> Brumpt, 1911, p. 908 (in France).

Onchocerca flexuosa.

> Wedl, 1856, p. 122 (in Germany).

Ostertagia cervi.

> Cameron, 1931, p. 214 (in Scotland).

Protostrongylus sagittatus.
>   Cameron, 1927, p. 11.
>   Railliet & Henry, 1907, p. 753.
Strongylus sp.
>   Brumpt, 1911, p. 908 (in France).
Trichuris ovis.
>   Brumpt, 1911, p. 908 (in France).
>   Rudolphi, 1819, p. 17.

Cervus eldi, *see* Rucervus eldii.

Cervus mexicanus, *see* Odocoileus mexicanus.

Cervus nambi, *see* Mazama nana.

Cervus paludosus, *see* Blastocerus dichotomus.

Cervus rufus, *see* Mazama americana.

Cervus simplicicornis, *see* Mazama simplicicornis.

Cervus unicolor, *see* Rusa unicolor.

Coassus nambi, *see* Mazama nana.

Coassus rufus, *see* Mazama americana.

DAMA DAMA (Linnæus, 1758) ; Fallow Deer.
>   Synonymy—*Cervus dama.*
>   Distribution—Europe and Western Asia.
>   Parasites—
>>   Dicrocoelium dendriticum.
>>>   Nicoll, 1923, p. 244 (in Britain).
>>   Fasciola hepatica.
>>>   Nicoll, 1923, p. 244 (in Britain).
>>>   Stroh, 1930, p. 389 (in Germany).
>>   Fasciola magna.
>>>   Nicoll, 1923, p. 244.
>>   Paramphistomum cervi.
>>>   Fischoeder, 1901, p. 368 (in Europe).
>>   Tænia hydatigena.
>>>   Weidman, 1913, p. 149.
>>   Chabertia ovina.
>>>   Ransom, 1911, p. 37.
>>   Cooperia curticei.
>>>   Rudolphi, 1819, p. 33 (in Germany).

Travassos, 1921, p. 32.

Yorke & Maplestone, 1926, p. 132.

Gongylonema spirale.

Baylis, 1925, p. 47.

Molin, 1857, p. 217.

Nematodirus filicollis.

Ransom, 1911, p. 84.

Nematodirus spathiger.

Travassos, 1921, p. 30.

Œsophagostomum venulosum.

Ransom, 1911, p. 47.

Ostertagia asymmetrica.

Ware, 1925, p. 38 (in England).

Trichuris ovis.

Rudolphi, 1819, p. 17.

MAZAMA AMERICANA (Erxleben, 1777) ; Red Brocket.

Synonymy—*Cariacus rufus.*

Cervus rufus.

Coassus rufus.

Mazama rufa.

Distribution—South America.

Parasites—

Paramphistomum liorchis.

Fischoeder, 1901, p. 368 (in Brazil).

Moniezia expansa.

Natterer in Diesing, 1850, p. 497 (in Brazil).

Tænia hydatigena.

Hall, 1919, p. 31.

Thysanosoma actinioides.

Diesing, 1850, p. 501 (in Brazil).

Eucyathostomum longesubulatum.

Molin, 1861, p. 460 (in Brazil).

Syngamus nasicola.

Linstow, 1899, p. 18 (in Brazil).

Trichuris, ovis.

Ransom, 1911, p. 112.

Mazama bezoartica, *see* Blastocerus bezoarticus.

Mazama hemionus, *see* Odocoileus hemionus.

Mazama mexicana, *see* Odocoileus mexicanus.

MAZAMA NANA (Kaup, 1839) ; Pygmy Brocket.

        Synonymy—*Cariacus nambi.*
                    Cervus nambi.
                    Coassus nambi.

        Distribution—South America.

        Parasites—

                Paramphistomum liorchis.

                        Fischoeder, 1901, p. 368 (in Brazil).

                Moniezia expansa.

                        Natterer in Diesing, 1850, p. 497 (in Brazil).

                Thysanosoma actinioides.

                        Diesing, 1850, p. 501 (in Brazil).

                Hæmonchus bispinosus.

                        Molin, 1860, p. 965 (in Brazil).

                        Travassos, 1921, p. 26.

                Setaria bidentata.

                        Molin, 1858, p. 401 (in Brazil).

                Spiroptera verrucosa.

                        Molin, 1860, p. 964 (in Brazil).

Mazama nemorivagus, *see* Mazama simplicicornis.

Mazama rufa, *see* Mazama americana.

MAZAMA SIMPLICICORNIS (Illiger, 1811) ; Brown Wood-Brocket.

        Synonymy—*Cervus simplicicornis.*
                    Mazama nemorivagus.

        Distribution—South America, Trinidad.

        Parasites—

                Paramphistomum liorchis.

                        Fischoeder, 1901, p. 368 (in Brazil).

                  Tænia hydatigena.

                        Diesing, 1850, p. 489.

                Thysanosoma actinioides.

                        Diesing, 1850, p. 501 (in Brazil).

                Hæmonchus contortus.

                        Travassos, 1921, p. 68 (in Brazil).

MAZAMA spp.

>Moniezia oblongiceps.
>
>>Stiles & Hassall, 1893, p. 35 (in South America).
>
>Hæmonchus contortus.
>
>>Ransom, 1911, p. 52.

ODOCOILEUS HEMIONUS (Rafinesque, 1817) ; Mule-Deer.

>Synonymy—*Cariacus macrotis.*
>
>>*Mazama hemionus.*
>
>Distribution—Western U.S.A. and Mexico.
>
>Parasites—
>
>>Tænia hydatigena.
>>
>>>Blair, 1903, p. 142.
>>
>>Tænia ovis (?).
>>
>>>Dikmans & Skinker, 1931, p. 55.
>>
>>Hæmonchus contortus.
>>
>>>Stiles & Hassall, 1901, p. 4.
>>
>>Protostrongylus macrotis.
>>
>>>Dikmans, 1931B, p. 3 (in Wyoming, U.S.A.).
>>
>>Trichostrongylus extenuatus.
>>
>>>Ransom, 1911, p. 94.
>>
>>Trichuris ovis.
>>
>>>Ransom, 1911, p. 112.

ODOCOILEUS MEXICANUS (Zimmermann, 1777) ; Mexican Deer.

>Synonymy—*Cariacus mexicanus.*
>
>>*Cervus mexicanus.*
>>
>>*Mazama mexicana.*
>
>Distribution—Mexico, U.S.A.
>
>Parasites—
>
>>Paramphistomum liorchis.
>>
>>>Fischoeder, 1901, p. 368.
>>
>>Tænia hydatigena.
>>
>>>Weidman, 1913, p. 149 (in U.S.A.).

ODOCOILEUS VIRGINIANUS (Boddaert, 1784) ; Virginia Deer, American Fallow Deer.

>Synonymy—*Cariacus virginianus.*

Distribution—Eastern U.S.A. and Southern Canada.

Parasites—

Fasciola magna.

Stiles & Hassall, 1908, p. 263.

Tænia hydatigena.

Hall, 1919, p. 31.

Ostertagia mossi.

Dikmans, 1931A, p. 2.

Ostertagia odocoilei.

Dikmans, 1931A, p. 1.

RANGIFER TARANDUS (Linnæus, 1758) ;   Reindeer, Caribou.

Synonymy—*Tarandus rangifer.*

Distribution—Northern Europe, Northern Asia and North
America.

Parasites—

Cittotænia dratchynskii.

Romanovitch, 1915, p. 451 (in Russia).

Echinococcus granulosus.

Hadwen, 1922, p. 39 (in Alaska).

Romanovitch, 1915, p. 452 (in Russia).

Moniezia expansa.

Railliet, 1886, p. 257.

Moniezia spp.

Hadwen, 1922, p. 39 (in Alaska).

Multiceps multiceps.

Beneden, 1861, p. 321.

Tænia hydatigena.

Beneden, 1861, p. 321.

Hadwen, 1922, p. 39 (in Alaska).

Romanovitch, 1915, p. 452 (in Russia).

Tænia krabbei.

Hadwen, 1922, p. 39 (in Alaska).

Moniez, 1879, p. 161.

1880, p. 44.

Tænia rangiferi.

Grüner, 1910, p. 952.

Dictyocaulus viviparus.

> Romanovitch, 1915, p. 452 (in Russia).

Dictyocaulus sp.

> Hadwen, 1922, p. 39 (in Alaska).

Nematodirella longispiculata.

> Romanovitch, 1915, p. 451 (in Russia).

> Yorke & Maplestone, 1926, p. 140.

Nematodirus sp.

> Hadwen, 1922, p. 39 (in Alaska).

Setaria tundra.

> Rajewsky, 1929, p. 41 (in Russia).

Skrjabinema tarandi.

> Skrjabin & Mizkewitsch, 1930, p. 183 (in Northern Russia).

RANGIFER TARANDUS TERRÆNOVÆ Bangs, 1896 ; Caribou.

Synonymy—*Rangifer terrænovæ.*

Distribution—Newfoundland.

Parasites—

Hæmonchus contortus.

> Ransom, 1911, p. 53.

Ostertagia circumcincta.

> Ransom, 1911, p. 62.

Trichostrongylus extenuatus.

> Ransom, 1911, p. 94.

Trichuris ovis.

> Ransom, 1911, p. 112.

Rangifer terrænovæ, *see* Rangifer tarandus terrænovæ.

RUCERVUS ELDII (M'Clelland, 1842) ; Thamin, Panolia Deer.

Synonymy—*Cervus eldi.*

Distribution—Burma, Siam, French Indo-China, India.

Parasites—

Paramphistomum cervi.

> Maplestone, 1923, pp. 117 and 203.

> Stiles & Goldberger, 1910, p. 78.

Paramphistomum orthocoelium.

> Maplestone, 1923, pp. 145 and 203.

> Stiles & Goldberger, 1910, p. 151.

Trichuris alcocki.

Linstow, 1906, p. 7 (in India).

Ransom, 1911, p. 115.

RUSA UNICOLOR (Kerr, 1792) ; Sambar, Elk in Ceylon.

Synonymy—*Cervus unicolor*.

Distribution—India, Ceylon, Malaya.

Parasites—

Fasciola magna.

Stiles & Hassall, 1908, p. 263.

Tænia hydatigena.

Hall, 1919, p. 31.

Tarandus rangifer, *see* Rangifer tarandus.

CERVIDÆ (Unspecified).

Parasites—

Ostertagia houdemeri.

Schwartz, 1927, p. 25 (in Indo-China).

Oxyurid (females alone available).

Dikmans, 1930, p. 52 (in Idaho, U.S.A.).

Setaria nudicauda.

Ortlepp, 1924, p. 21.

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Index to Vol. IX.

Index of Authors.

New Names in Volume IX.

Corrigenda for Volume IX.

Page 111, lines 6 and 11 from top, for " SYNTHETOCAULUS read
  " PROTOSTRONGYLUS."

Page 150, line 13 from bottom, for " 1903 " read " 1913."

Page 151, in legend to figure, for " *Oslerius* " read " *Oslerus.*"

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Page 258, line 3 from top, for " *CRENOSOMA* Buckley, 1930 " read
  " *CRENOSOMA POTOS* Buckley, 1930."